DOCUMENT RESUME

ED 195 793 CE 027 476

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TITLE	Basic Electronics I.
INSTITUTION	Mid-America Vocational Curriculum Consortium, Stillwater, Okla.
PUB DATE	80
NOTE	849p.: Colored pages may not reproduce clearly.
EDRS PRICE	MF05 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS	Behavioral Objectives; Course Content; Curriculum Guides; Electric Circuits; *Electricity; Electronic Equipment; *Electronics; *Electronics Industry; Instructional Materials; Job Application; Learning Activities; Postsecondary Education; Secondary Education; Units of Study; *Vocational Education

ABSTRACT

Designed for use in basic electronics programs, this curriculum guide is comprised of twenty-nine units of instruction in five major content areas: Orientation, Basic Principles of Electricity/Electronics, Fundamentals of Direct Current, Fundamentals of Alternating Current, and Applying for a Job. Each instructional unit includes some or all of the basic components of a unit of instruction: performance objectives, suggested activities for teachers and students, information sheets, assignment sheets, visual aids, tests, and answers to the test. It is noted that each unit is planned for more than one lesson or class period of instruction. Among the units included in section 3, Fundamentals of Direct Current, are the following: Circuit Fudamentals, Resistence, Voltage and Measurement, Conductors and Insulators, Series Circuits, and Magnetism. In the fourth section unit topics include The Nature of Alternating Current, Inductance, Capacitance, and Capacitive Reactance. (IRA)

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ED195793

BASIC ELECTRONICS I

by
L. Paul Robertson

Developed by the
Mid-America Vocational Curriculum Consortium, Inc.

CE 027 476

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ACKNOWLEDGMENTS

Appreciation is extended to those individuals who contributed their time and talents to the development of *Basic Electronics I*.

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Norman A. Pederson	Sioux Falls, South Dakota
Jesse J. Simms	Dickinson, Texas
Ralph D. Bittle	Tecumseh, Oklahoma
Norbert J. Atherton	Wichita, Kansas
Harry Matsunaka	Fort Collins, Colorado
Howie DiBlasi	Lake Havasu, Arizona

Thanks are extended to Richard Tinnell, Teacher Educator from Oklahoma State University and David Merrill, State Supervisor of Technical and Industrial Education, South Dakota, for their assistance and input into the development of this publication.

Special thanks are extended to Mel Winegarten, of the Electrician's Joint Apprenticeship and Training Committee, Tulsa, Oklahoma for his contributions to the development of this book.

Gratitude is expressed to Regina Decker, Dan Fulkerson, and Kathy Dolan for editing and to Wendy Rodebaugh and Teddi Cox for typing.

Appreciation is extended to Bill Dunn, Candy Meyer, Lin Thurston, and Edith Mekis for the illustrations and drawings used in this publication.

The printing staff of the Occupational Curriculum Lab, East Texas State University, Commerce, Texas is deserving of much credit for printing this publication.

USE OF THIS PUBLICATION

Instructional Units

The *Basic Electronics I* curriculum includes 29 units. Each instructional unit includes some or all of the basic components of a unit of instruction: performance objectives, suggested activities for teachers and students, information sheets, assignment sheets, visual aids, tests, and answers to the test. Units are planned for more than one lesson or class period of instruction.

Careful study of each instructional unit by the teacher will help determine:

A. The amount of material that can be covered in each class period
B. The skills which must be demonstrated
  1. Supplies needed
  2. Equipment needed
  3. Amount of practice needed
  4. Amount of class time needed for demonstrations
C. Supplementary materials such as pamphlets or filmstrips that must be ordered
D. Resource people who must be contacted

Objectives

Each unit of instruction is based on performance objectives. These objectives state the goals of the course, thus providing a sense of direction and accomplishment for the student.

Performance objectives are stated in two forms: unit objectives, stating the subject matter to be covered in a unit of instruction; and specific objectives, stating the student performance necessary to reach the unit objective.

Since the objectives of the unit provide direction for the teaching-learning process, it is important for the teacher and students to have a common understanding of the intent of the objectives. A limited number of performance terms have been used in the objectives for this curriculum to assist in promoting the effectiveness of the communication among all individuals using the materials.

Following is a list of performance terms and their synonyms which may have been used in this material:

Name	Identify	Describe
Label	Select	Define
List in writing	Mark	Discuss in writing
List orally	Point out	Discuss orally
Letter	Pick out	Interpret
Record	Choose	Tell how
Repeat	Locate	Tell what
Give		Explain

Order
Arrange
Sequence
List in order
Classify
Divide
Isolate

Distinguish
Discriminate

Construct
Draw
Make
Build
Design
Formulate
Reproduce
Transcribe
Reduce
Increase
Figure

Demonstrate
Show your work
Show procedure
Perform an experiment
Perform the steps
Operate
Remove
Replace
Turn off/on
(Dis) assemble
(Dis) connect

Additional Terms Used
Evaluate
Complete
Analyze
Calculate
Estimate
Plan
Observe
Compare
Determine
Perform

Prepare
Make
Read
Tell
Teach
Converse
Lead
State
Write

Reading of the objectives by the student should be followed by a class discussion to answer any questions concerning performance requirements for each instructional unit.

Teachers should feel free to add objectives which will fit the material to the needs of the students and community. When teachers add objectives, they should remember to supply the needed information, assignmnet and/or job sheets, and criterion tests.

Suggested Activities

Each unit of instruction has a suggested activities sheet outlining steps to follow in accomplishing specific objectives. The activities are listed according to whether they are the responsibility of the instructor or the student.

Instructor: Duties of the instructor will vary according to the particular unit; however, for best use of the material they should include the following: provide students with objective sheet, information sheet, assignment sheets, and job sheets; preview filmstrips, make transparencies, and arrange for resource materials and people; discuss unit and specific objectives and information sheet; give test. Teachers are encouraged to use any additional instructional activities and teaching methods to aid students in accomplishing the objectives.

Information Sheets

Information sheets provide content essential for meeting the cognitive (knowledge) objectives in the unit. The teacher will find that the information sheets serve as an excellent guide for presenting the background knowledge necessary to develop the skill specified in the unit objective.

Students should read the information sheets before the information is discussed in class. Students may take additional notes on the information sheets.

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FOREWORD

The Mid-America Vocational Curriculum Consortium (MAVCC) was organized for the purpose of developing instructional material for the twelve member states. Priorities for developing MAVCC material are determined annually based on the needs as identified by all member states. One priority identified was basic electronics. This publication is a part of a project designed to provide the needed instructional material for basic electronics programs.

The success of this publication is due, in large part, to the capabilities of the personnel who worked with its development. The technical writers have numerous years of industry as well as teaching experience. Assisting them in their efforts were representatives of each of the member states who brought with them technical expertise and the experience related to the classroom and to the trade. To assure that the materials would parallel the industry environment and be accepted as a transportable basic teaching tool, organizations and industry representatives were involved in the developmental phases of the manual. Appreciation is extended to them for their valuable contributions to the manual.

This publication is designed to assist teachers in improving instruction. As these publications are used, it is hoped that the student performance will improve and that students will be better able to assume a role in their chosen occupation, basic electronics.

Instructional materials in this publication are written in terms of student performance using measurable objectives. This is an innovative approach to teaching that accents and augments the teaching/learning process. Criterion referenced evaluation instruments are provided for uniform measurement of student progress. In addition to evaluating recall information, teachers are encouraged to evaluate the other areas including process and product as indicated at the end of each instructional unit.

It is the sincere belief of the MAVCC personnel and all those members who served on the committees that this publication will allow the students to become better prepared and more effective members of the work force.

David Merrill,
Chairman
Board of Directors
Mid-America Vocational
Curriculum Consortium

PREFACE

For many years those responsible for teaching basic electronics have felt a need for instructional materials to use in this area. A team of teachers, industry representatives, and trade and industrial education staff members accepted this challenge and have produced manuals which will meet the needs of many types of courses where students are expected to become proficient in the area of electronics. The MAVCC *Basic Electronics I* publication is designed to include the basic information needed to be able to attain that proficiency.

As with all efforts of this nature, feedback from the instructors selected to use these curriculum materials will greatly assist MAVCC in evaluating its effort and contribute significantly to plans for future material development.

Every effort has been made to make this publication basic, readable and by all means usable. Three vital parts of instruction have been intentionally omitted from this publication: motivation, personalization, and localization. These areas are left to the individual instructors and the instructors should capitalize on them. Only then will this publication really become a vital part of the teaching-learning process.

Ann Benson
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  Curriculum Consortium, Inc.

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Transparency Masters

Transparency masters provide information in a special way. The students may see as well as hear the material being presented, thus reinforcing the learning process. Transparencies may present new information or they may reinforce information presented in the information sheets. They are particularly effective when identification is necessary.

Transparencies should be made and placed in the notebook where they will be immediately available for use. Transparencies direct the class's attention to the topic of discussion. (NOTE: Stand away from the overhead projector when discussing transparency material. The noise of the projector may cause the teacher to speak too loudly.)

Assignment Sheets

Assignment sheets give direction to study and furnish practice for paper and pencil activities to develop the knowledges which are necessary prerequisites to skill development. These may be given to the student for completion in class or used for homework assignments. Answer sheets are provided which may be used by the student and/or teacher for checking student progress.

Job Sheets

Job sheets are an important segment of each unit. The instructor should be able to and in most situations should demonstrate the skills outlined in the job sheets. Procedures outlined in the job sheets give direction to the skill being taught and allow both student and teacher to check student progress toward the accomplishment of the skill. Job sheets provide a ready outline for students to follow if they have missed a demonstration. Job sheets also furnish potential employers with a picture of the skills being taught and the performances which might reasonably be expected from a person who has had this training.

Test and Evaluation

Paper-pencil and performance tests have been constructed to measure student achievement of each objective listed in the unit of instruction. Individual test items may be pulled out and used as a short test to determine student achievement of a particular objective. This kind of testing may be used as a daily quiz and will help the teacher spot difficulties being encountered by students in their efforts to accomplish the unit objective. Test items for objectives added by the teacher should be constructed and added to the test.

Test Answers

Test answers are provided for each unit. These may be used by the teacher and/or student for checking student achievement of the objectives.

BASIC ELECTRONICS

INSTRUCTIONAL ANALYSIS

Job Training: What the
Worker Should Be Able to Do
(Psychomotor)

Related Information: What
the Worker Should Know
(Cognitive)

SECTION A--ORIENTATION

UNIT I: EXPECTATIONS

1. Terms
2. Employment possibilities
3. Technical-industrial team
4. Places of employment
5. Contents
6. Teacher/student responsibilities
7. Steps

UNIT II: SAFETY

1. Terms
2. Hazards
3. Electrical shock
4. Treatment for shock
5. Fire types and classes
6. Fire extinguishers
7. Colors
8. Lab safety rules
9. Personal safety rules
10. Hand tool safety
11. Power tool safety
12. Electrical cord safety
13. Fire drill
14. Safety pledge

Job Training: What the Worker Should Be Able to Do (Psychomotor)

Related Information: What the Worker Should Know (Cognitive)

UNIT III: HAND TOOLS

1. Hand tools
2. Tool uses
3. Selection of tools
4. Maintenance
5. Clean and lubricate pliers
6. Adjust wire strippers

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1. Terms
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3. Inner and outer orbits
4. Electrons
5. Electrical charges
6. Create and observe the behavior of charges

UNIT II: SOURCES OF ELECTRICAL ENERGY

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5. Generate electricity with magnetism
6. Generate electricity with pressure
7. Generate electricity with heat
8. Generate electricity with light

Job Training: What the
Worker Should Be Able to Do
(Psychomotor)

Related Information: What
the Worker Should Know
(Cognitive)

SECTION C--FUNDAMENTALS OF DIRECT CURRENT

UNIT I: CIRCUIT FUNDAMENTALS

1. Terms
2. Coulomb's law
3. Charges
4. Voltage, current and resistance
5. Circuit characteristics
6. Schematic symbols
7. Circuit schematic
8. Current flow
9. Open and closed circuits
10. Construct a basic circuit from a schematic

UNIT II: SOLDERING AND CIRCUIT FABRICATION

1. Terms
2. Soldering tools
3. Cleaning
4. Stripping and tinning
5. Soldering procedures
6. Characteristics
7. Poor solder connections
8. Degrees of mechanical security
9. Strip and tin wire for soldered connections
10. Solder wires to turret terminals, then de-solder wires
11. Solder wire to a terminal strip

Job Training: What the
Worker Should Be Able to Do
(Psychomotor)

Related Information: What
the Worker Should Know
(Cognitive)

12. Repair a printed circuit board by replacing resistors and correcting open or broken lands

13. Splice wires together by means of soldering and crimping

14. Connect ends of flexible printed wiring

UNIT III: SCIENTIFIC CALCULATIONS

1. Terms
2. Data keys
3. Function keys
4. Number system
5. Systems of numeration
6. Scientific notation
7. Laws of exponents
8. Computations
9. Trigonometry functions

10. Use an electronic calculator

11. Solve combined multiplication and division problems

12. Convert numbers between binary and decimal systems

13. Express numbers in scientific and engineering notation

14. Obtain trigonometry function values

15. Determine logarithms of numbers

UNIT IV: RESISTANCE

1. Terms
2. Fixed resistors
3. Adjustable resistors

Job Training: What the Worker Should Be Able to Do (Psychomotor)	Related Information: What the Worker Should Know (Cognitive)
	4. Composition of fixed resistors
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	7. Resistor symbols
	8. Resistor values
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Job Training: What the Worker Should Be Able to Do (Psychomotor)	Related Information: What the Worker Should Know (Cognitive)
UNIT VI: CURRENT AND MEASUREMENT	
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Job Training: What the Worker Should Be Able to Do (Psychomotor)	Related Information: What the Worker Should Know (Cognitive)
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	3. Ohm's Law
	4. Circular expression
	5. Uses
	6. Solving for unknown voltage
	7. Solving for unknown current
	8. Solving for unknown resistance
9. Use Ohm's law with circuit measurements	
UNIT X: SERIES CIRCUITS	
	1. Terms
	2. Abbreviations
	3. Rules
	4. Direct/partial short circuits

Job Training: What the Worker Should Be Able to Do (Psychomotor)	Related Information: What the Worker Should Know (Cognitive)
	5. Total voltage
	6. Voltage drops
	7. Total resistance
	8. Current
	9. Unknown circuit value
	10. Unknown values
	11. Power
12. Measure voltage drops in a series circuit	
13. Analyze current values in a series circuit	
14. Analyze resistance and power in a series circuit	

UNIT XI: PARALLEL CIRCUITS

	1. Terms
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	4. Formula
	5. Circuit analysis
	6. Opens and shorts
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8. Measure power in a parallel circuit	

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	2. Symbols
	3. Kirchhoff's current law
	4. Simplifying

Job Training: What the Worker Should Be Able to Do (Psychomotor)	Related Information: What the Worker Should Know (Cognitive)
	5. Function of ground
	6. Functions of voltage divider
7. Measure and calculate quantities in series-parallel circuits	
8. Construct a voltage divider and analyze its function	

UNIT XIII: MAGNETISM

Job Training: What the Worker Should Be Able to Do (Psychomotor)	Related Information: What the Worker Should Know (Cognitive)
	1. Terms
	2. Magnets
	3. Producing artificial magnets
	4. Types
	5. Lines of force, fields, flux, and flux density
	6. Left-hand rules
	7. Induction
	8. Application of induction
9. Show the existence of magnetic lines of force around a magnet	
10. Demonstrate that magnetic poles can attract and repel	
11. Construct a simple electromagnet and check its operation	

UNIT XIV: MOTORS

Job Training: What the Worker Should Be Able to Do (Psychomotor)	Related Information: What the Worker Should Know (Cognitive)
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	3. Motor action
	4. Motor torque
	5. Increasing motor torque
	6. Motor efficiency

Job Training: What the Worker Should Be Able to Do (Psychomotor)	Related Information: What the Worker Should Know (Cognitive)
	7. Formula
	8. DC motor parts
	9. Direction of fields, currents, and motor action
	10. Motor power and efficiency
	11. Torque and flow
12. Produce motor action from a current-carrying conductor in a magnetic field	
13. Calculate horsepower of a small motor	

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	6. Sine functions
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	8. Frequency, period, and wavelength
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	10. Sine wave conversions
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13. Construct a sine wave cycle	

Job Training: What the Worker Should Be Able to Do (Psychomotor)	Related Information: What the Worker Should Know (Cognitive)
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	4. Left hand rule
	5. Magnitude
	6. Elementary cycle generation
	7. Generator construction
	8. Rules
	9. Voltage phasors
	10. Phase angle diagrams
	11. Three-phase power
	12. Current flow direction
	13. AC cycle instantaneous values
14. Construct a simple generator	
15. Identify generator components	
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	2. Abbreviations
	3. Factors
	4. Lenz's law
	5. Formula for a henry
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	7. Kinds
	8. Formulas
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Job Training: What the Worker Should Be Able to Do (Psychomotor)	Related Information: What the Worker Should Know (Cognitive)
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12. Determine transformer ratios	

UNIT IV: INDUCTIVE REACTANCE

	1. Terms
	2. Symbols
	3. Factors
	4. Formula
	5. Current and voltage relationships
	6. Applied voltage and impedance
	7. Formulas for determining true power
	8. Formulas for determining apparent power
	9. Formulas for determining reactive power
	10. Formulas for determining power factor
	11. Formula for determining quality factor
	12. Inductive time constants
	13. Labels on chart
	14. Compute inductive reactance
	15. Compute applied voltage and impedance
	16. Compute power
	17. Compute the Q
	18. Time constant problems

Job Training: What the Worker Should Be Able to Do (Psychomotor)	Related Information: What the Worker Should Know (Cognitive)
19. Show the effect of inductance in AC circuits	
20. Solve for values of an operating RL circuit	

UNIT V: CAPACITANCE

	1. Terms
	2. Symbols and abbreviations
	3. Functions
	4. Capacitor construction
	5. DC charging and discharging
	6. Formula for capacitance
	7. Formula for total capacitance in parallel
	8. Formula for total capacitance when unequal
	9. Formula for total capacitance of equal value
	10. Formula for total capacitance of equal value
	11. Types
	12. Rules in color coding
	13. Capacitance values
14. Test capacitors with an ohmmeter	
15. Examine the construction of a capacitor	
16. Determine the effect of AC and DC on capacitors	

Job Training: What the Worker Should Be Able to Do
(Psychomotor)

Related Information: What the Worker Should Know
(Cognitive)

UNIT VI: RC TIME CONSTANTS

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3. Waveshapes during charge
4. Discharging an RC circuit
5. Waveshapes during discharge
6. Computing time constant
7. Horizontal and vertical axes
8. Exponential formulas for voltage
9. Exponential formula for charge current
10. Exponential formula for voltage during discharge
11. Characteristics
12. Computations
13. Determine time constants of RC circuits
14. Construct a neon bulb flasher

UNIT VII: CAPACITIVE REACTANCE

1. Terms
2. Symbols
3. Formula for capacitive reactance
4. Inverse proportion
5. Current and voltage
6. Applied voltage, impedance, and power factor
7. True, apparent, reactive power and power factor

Job Training: What the Worker Should Be Able to Do (Psychomotor)	Related Information: What the Worker Should Know (Cognitive)
	8. Figure of merit
	9. Capacitive reactance
	10. Phase relationships
	11. Values
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13. Determine capacitive reactance and impedance in RC circuits	

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	1. Terms
	2. Reactance
	3. Impedance
	4. Computing impedance
	5. Voltages
	6. Computing applied voltage
	7. Conditions
	8. Resonant frequency
	9. Resonant frequency variation
	10. The Q of series circuit
	11. Bandwidth
	12. Reactance
	13. Impedance
	14. Parameters
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Job Training: What the
Worker Should Be Able to Do
(Psychomotor)

Related Information: What
the Worker Should Know
(Cognitive)

UNIT IX: PARALLEL RCL CIRCUITS

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3. Formula for total current
4. Formula for impedance
5. Resonance
6. Formula for resonant frequency
7. Tuned circuits
8. The Q of parallel circuit
9. Bandwidth
10. Characteristics
11. Problems-RL and RCL circuits
12. Problems-RCL circuits
13. Analysis of circuit

14. Determine the resonant frequency of an RCL parallel circuit

SECTION E--APPLYING FOR A JOB

UNIT I: APPLYING FOR A JOB

1. Terms
2. Sources
3. Methods
4. Application forms
5. Expectations
6. Attributes and attitudes
7. Conduct
8. Resume
9. Letter of application

Job Training: What the Worker Should Be Able to Do (Psychomotor)	Related Information: What the Worker Should Know (Cognitive)
	10. Complete application form
	11. Follow-up letter

EXPECTATIONS
UNIT I

UNIT OBJECTIVE

After completion of this unit, the student should be able to state reasons why the electronics field is a good field for employment in today's world and name places of electronics technician employment opportunities in industry. The student should also be able to arrange in order the steps involved in electronics repair. This knowledge will be evidenced by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms associated with expectations of the electronics field to their definitions or descriptions.
2. State four reasons why the electronics field is a good field for employment.
3. Select true statements about the technical-industrial team.
4. Name places of employment opportunities for electronics technicians.
5. Select true statements about the contents of this course.
6. List teacher and student responsibilities in the electronics program.
7. Arrange in order the steps involved in electronics repair.

EXPECTATIONS
UNIT I

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information sheet.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information sheet.

VI. Take students on tour of local electronics firm to observe technicians at work. Ask a technician or former student to give brief talk on technician opportunities and duties.

VII. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

    A. Objective sheet

    B. Information sheet

    C. Transparency masters

        1. TM 1--The Technical-Industrial Team

        2. TM 2--The Spectrum of Technical Education

    D. Test

    E. Answers to test

II. Reference--*Radio Amateur's Handbook.* Newington, CT: American Radio Relay League.

EXPECTATIONS
UNIT I

INFORMATION SHEET

I. Terms and definitions

A. Electricity--An invisible force that can produce heat, light, or motion by the movement of small particles of matter called electrons

(NOTE: Lightning is an example of electricity that is controlled by nature, not people. An example of human-controlled use of electricity is the electric stove.)

B. Electronics--The controlled use of electricity in vacuums, gases, liquids, or vapors, and in certain semiconductor materials

(NOTE: Electronics applications include the radio, hi-fi systems, television, computers, and digital control.)

C. Automation--A system by which machinery or electronic devices operate and regulate themselves with little or no control by people

D. Scientist--A person who studies the laws of nature in order to learn how to control them for society's betterment

E. Engineer--A person who designs useful products on the basis of scientific knowledge

(NOTE: Airplane engineers design aircraft which function according to the laws of gravity established by Isaac Newton.)

F. Technician--A person who assists the scientist and engineer in their work and helps design, build, install, and maintain the products

G. Craftsworker--A person who is skilled in performing some part of the building or fabrication of a product

(NOTE: The technician's training involves some scientific theory, and the technician may possess many skills applicable to the design, fabrication, and maintenance of a product. A craftsworker's training involves little, if any, scientific theory, and the craftsworker's skill is usually limited to a single specialty, such as carpentry, metal working, welding, and soldering.)

H. Federal Communications Commission (FCC)--A United States government agency which regulates all electronics communication within this country

Examples: Radio, television, CB's, telephone, telegraph

I. Troubleshooting--A systematic method of locating the cause of a problem or malfunction in electrical or electronic equipment

INFORMATION SHEET

II. Reasons why the electronics field is a good field for employment

  A. New types of electronic equipment are constantly being developed for industry

    Examples: Business machines, computers, television, lasers, automated machines

  B. Consumers are buying more electronic devices and appliances for use at home

    Examples: All-electric homes, home fire and burglar alarm systems, microwave cooking systems, automatic washing machines and dryers, stereo sound systems, automatic cameras, and home entertainment devices

  C. Present technicians are continuously retiring

  D. There are opportunities for self-employment

    Examples: Repair and maintenance shops, replacement parts sales

III. The technical-industrial team (Transparencies 1 and 2)

  A. Scientists and engineers

    1. Work is about 90% theoretical, 10% skill

    2. Typical activities--Research, development, planning, design, invention, and publication of results

    3. Education required--Four or more years of college

  B. Engineering technician

    1. Work is about 60% theoretical, 40% skill

    2. Typical activities

      a. Assist in design and system planning

      b. Operate, modify, troubleshoot, and repair equipment

      c. Record and report results

    3. Education required--Two to four years post-secondary school or junior/senior college

  C. Industrial technicians

    1. Work is about 40% theoretical, 60% skill

INFORMATION SHEET

2. Typical activities
    a. Machine operation
    b. Preventive maintenance
    c. Troubleshooting and repair of equipment
3. Education required--Two years post-secondary school or junior college

D. Service technicians and craftsworkers

1. Work is about 10% theoretical, 90% skill
2. Typical activities
    a. Equipment servicing and limited repair
    b. Hand and machine tool operation
3. Education required--High school or vocational school; some post-secondary schooling

IV. Places of employment opportunities for electronics technicians

A. Independent repair shops

1. Consumer electronics repair shop
2. Radio and television equipment repair shop

    (NOTE: Repair of communication equipment and systems requires licensing by the Federal Communications Commission.)

3. Automotive and aircraft electronic equipment repair shop

B. Large private repair and servicing firms

1. Service organizations
2. Technical representatives
3. Manufacturers
4. Merchandisers

C. Government agencies

1. Military services

    (NOTE: This includes the Army, Navy, Air Force, Marines, National Guard, and Coast Guard.)

INFORMATION SHEET

2. Government laboratories
3. Government Bureau of Standards
4. State and local government service departments

D. National communications industries

1. Radio and television networks
2. Telephone and telegraph companies
3. Satellite communications
4. Microwave and laser communication industries
5. Computer industries

V. Contents of this course

A. Basic studies

(NOTE: This occurs early in the course.)

1. Safety
2. The laws which govern electricity

   Examples: Ohm's law, Kirchhoff's law, Watt's law

3. The sources of electricity and magnetism
4. How electricity behaves under certain conditions
5. How electricity is used in our daily lives

B. Advanced studies

(NOTE: The following are studied later in the course.)

1. The fundamentals of electronic circuitry
2. The nature and use of electronic components

   Examples: Resistors, capacitors, inductors, and active devices

3. The function of components in electronic systems, such as, radio, television, radar, and sonar
4. How to test, troubleshoot, and repair electronic components and systems

INFORMATION SHEET

C. Laboratory work

(NOTE: Laboratory work will occur throughout the course.)

1. How to use test and measuring equipment
2. How to build electronic circuits
3. How to draw schematics, block diagrams, and wiring diagrams of electronic circuits
4. How to test, troubleshoot, and repair circuits

VI. Teacher and student responsibilities in the electronics program

A. Teacher responsibilities

1. Supervises the classroom
2. Provides for student's needs
3. Makes sure safety is practiced in the lab
4. Requires students to follow directions

B. Student responsibilities

1. Follow safety rules and lab regulations without exception
2. Attend class regularly and on time
3. Refrain from causing distractions
4. Follow directions exactly
5. Ask for help when needed
6. Never perform an operation which is not understood
7. Complete assigned work without being reminded
8. Have pride and enthusiasm in work

VII. Steps involved in electronics repair

A. Analysis of symptoms

1. Operate or attempt to operate the equipment
2. Observe what appears to be wrong
3. Diagnose the cause of the problem

   (NOTE: This diagnosis should be based on knowledge of how the equipment functions.)

INFORMATION SHEET

B. Troubleshooting

1. Obtain specifications or fact sheets for the equipment

   (NOTE: Every manufacturer of electronic equipment provides specifications which state what output should be measured at various parts of the circuit.)

2. Using proper test equipment, isolate the trouble and measure for correct outputs or signals at various parts of the circuit, especially in the area where the trouble is suspected
3. Continue test and measurement using mid-point techniques until problem is identified
4. Determine which component or components are the cause of the faulty indications
5. Repair or attach tag to equipment briefly describing trouble, faulty test indications, and component(s) to be replaced

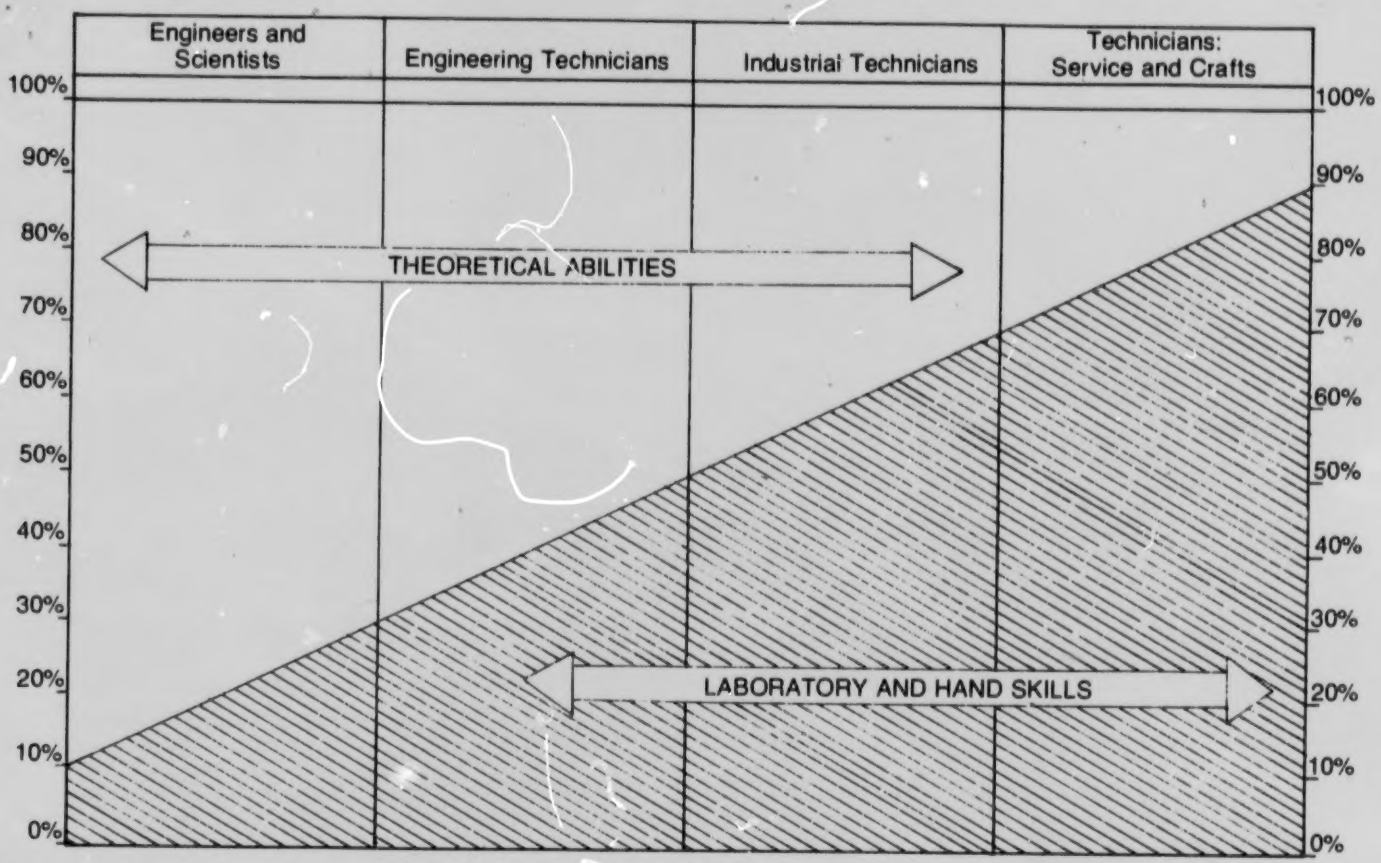
C. Repair

1. Disassemble the equipment
2. Remove the faulty component(s)
3. Install the new component(s)
4. Reassemble the equipment

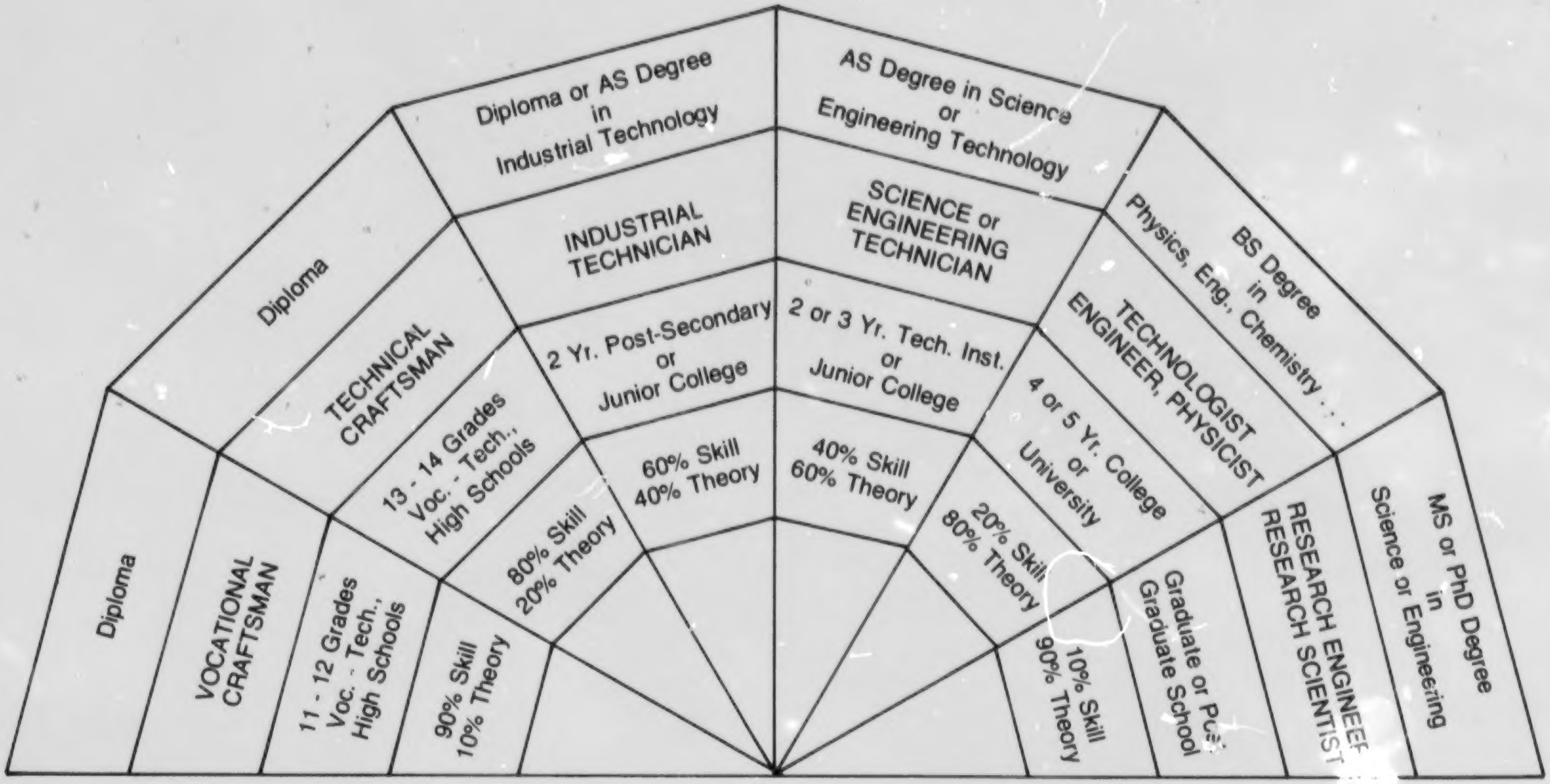
D. Recertification

1. Check for proper circuit outputs
2. Adjust current or voltage levels as necessary
3. Operate equipment to make sure trouble symptoms are removed

The Technical-Industrial Team



The Spectrum of Technical Education


Diploma
Diploma or AS Degree in Industrial Technology
AS Degree in Science or Engineering Technology
BS Degree in Physics, Eng., Chemistry . . .
MS or PhD Degree in Science or Engineering
Diploma
TECHNICAL CRAFTSMAN
INDUSTRIAL TECHNICIAN
SCIENCE or ENGINEERING TECHNICIAN
TECHNOLOGIST ENGINEER, PHYSICIST
RESEARCH ENGINEER RESEARCH SCIENTIST
VOCATIONAL CRAFTSMAN
13 - 14 Grades Voc. - Tech., High Schools
2 Yr. Post-Secondary or Junior College
2 or 3 Yr. Tech. Inst. or Junior College
4 or 5 Yr. College or University
Graduate or Post Graduate School
11 - 12 Grades Voc. - Tech., High Schools
80% Skill 20% Theory
60% Skill 40% Theory
40% Skill 60% Theory
20% Skill 80% Theory
90% Skill 10% Theory
10% Skill 90% Theory

EXPECTATIONS
UNIT I

NAME ____________________

TEST

1. Match the terms on the right to the correct definitions or descriptions.

_____a. A person who studies the laws of nature in order to learn how to control them for society's betterment

_____b. A system by which machinery or electronic devices operate and regulate themselves with little or no control by people

_____c. A United States government agency which regulates all electronics communication within this country

_____d. An invisible force that can produce heat, light, or motion by the movement of small particles of matter called electrons

_____e. A person who assists the scientist and engineer in their work and helps design, build, install, and maintain the products

_____f. A systematic method of locating the cause of a problem or malfunction in electrical or electronic equipment

_____g. The controlled use of electricity in vacuums, gases, liquids, or vapors, and in certain semiconductor materials

_____h. A person who designs useful products on the basis of scientific knowledge

_____i. A person who is skilled in performing some part of the building or fabrication of a product

1. Electricity
2. Electronics
3. Automation
4. Scientist
5. Engineer
6. Technician
7. Craftsworker
8. Federal Communications Commission (FCC)
9. Troubleshooting

2. State four reasons why the electronics field is a good field for employment.

a.

b.

c.

d.

3. Select true statements about the technical-industrial team by placing an "X" in the appropriate blanks.

   ______a. The technical-industrial team consists only of scientists and engineers

   ______b. The technical-industrial team consists of scientists, engineers, technicians, and craftsworkers

   ______c. The work of an engineering technician is about 60% theoretical and 40% skill

   ______d. The education required to become an engineer includes only high school or vocational school

   ______e. A craftsworker's activities include product design and research for new products

   ______f. An industrial technician's activities include troubleshooting and repair of equipment

   ______g. A scientist's work is about 10% theoretical and 90% skill

4. Name two places of employment opportunities for electronics technicians in each of the following areas of electronics work:

   a. Independent repair shops

      1)

      2)

   b. Large private repair and servicing firms

      1)

      2)

   c. Government agencies

      1)

      2)

   d. National communications industries

      1)

      2)

5. Select true statements about the contents of this electronics course by placing an "X" in the appropriate blanks.

   ______a. The laws which govern electricity

   ______b. How to use a plow

_____c. How to read a compass

_____d. How electricity is used in our daily lives

_____e. How to test,troubleshoot, and repair circuits

_____f. How to change an automobile tire

_____g. How to fly an airplane

_____h. The nature and use of electronic components

_____i. How to determine the best price of a power supply

_____j. How to use test and measuring equipment

_____k. How to repair plumbing

_____l. How to build electronic circuits

6. List two teacher responsibilities and five student responsibilities in the electronics program.

    a. Teacher responsibilities

        1)

        2)

    b. Student responsibilities

        1)

        2)

        3)

        4)

        5)

7. Arrange in order the following electronics repair steps by numbering them from 1 to 15.

_____a. Disassemble the equipment

_____b. Diagnose the cause of the problem

_____c. Using proper test equipment, isolate the trouble and measure for correct outputs or signals at various parts of the circuit, especially in the area where trouble is suspected

_____d. Operate or attempt to operate the equipment

_____e. Adjust current or voltage levels as necessary _____f. Reassemble the equipment

_____g. Observe what appears to be wrong

_____h. Obtain specifications or fact sheets for the equipment

_____i. Repair or attach tag to equipment briefly describing trouble, faulty test indications, and component(s) to be replaced

_____j. Remove the faulty component(s)

_____k. Install the new component(s)

_____l. Operate equipment to make sure trouble symptoms are removed

_____m. Continue test and measurement using mid-point techniques until problem is identified

_____n. Determine which component or components are the cause of the faulty indications

_____o. Check for proper circuit outputs

EXPECTATIONS
UNIT I

ANSWERS TO TEST

1. a. 4
   b. 3
   c. 8
   d. 1
   e. 6
   f. 9
   g. 2
   h. 5
   i. 7

2. a. New types of electronic equipment are constantly being developed for industry
   b. Consumers are buying more electronic devices and appliances for use at home
   c. Present technicians are continuously retiring
   d. There are opportunities for self-employment

3. b, c, f

4. Any two of the following under each area:

   a. 1) Consumer electronics repair shop
      2) Radio and television equipment repair shop
      3) Automotive and aircraft electronic equipment repair shop

   b. 1) Service organizations
      2) Technical representatives
      3) Manufacturers
      4) Merchandisers

   c. 1) Military services
      2) Government laboratories
      3) Government Bureau of Standards
      4) State and local government service departments

   d. 1) Radio and television networks
      2) Telephone and telegraph companies
      3) Satellite communications
      4) Microwave and laser communication industries
      5) Computer industries

5. a, d, e, h, j, l

6. Any two under teacher responsibilities and any five under student responsibilities:

   a. Teacher responsibilities

      1) Supervises the classroom
      2) Provides for student's needs
      3) Makes sure safety is practiced in the lab
      4) Requires students to follow directions

b. **Student responsibilities**

1) Follow safety rules and lab regulations without exception
2) Attend class regularly and on time
3) Refrain from causing distractions
4) Follow directions exactly
5) Ask for help when needed
6) Never perform an operation which is not understood
7) Complete assigned work without being reminded
8) Have pride and enthusiasm in work

7.

a.	9	f.	12	k.	11
b.	3	g.	2	l.	15
c.	5	h.	4	m.	6
d.	1	i.	8	n.	7
e.	14	j.	10	o.	13

SAFETY
UNIT II

UNIT OBJECTIVE

After completion of this unit, the student should be able to name hazards of working with electrical and electronics systems and state the use and method of operation for common types of fire extinguishers. The student should also be able to select safety rules which apply to the proper use of hand tools, safety rules which should be observed when using power tools, and rules for the safe use of electrical cords. This knowledge will be evidenced by correctly performing the procedures outlined on the assignment sheets and scoring 100% on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match the terms associated with electrical safety to the correct definitions.
2. Name four hazards of working with electrical and electronics equipment.
3. Select true statements concerning electrical shock.
4. Select statements that describe the correct procedure when treating a victim of electrical shock.
5. Match the four fire classes (A, B, C, and D) with the type of fire which each class identifies.
6. State the use (class of fire) and operation of four common types of fire extinguishers.
7. Match the six colors used in color coding with the type of hazard they designate.
8. Select statements which describe good general lab safety rules.
9. Select statements which describe good personal safety rules.
10. Select the safety rules which describe hand tool safety precautions.
11. Select the safety rules which describe power tool safety precautions.
12. Select statements which describe rules for safe use of electrical cords.
13. Properly plan and execute a class fire drill.
14. Indicate a willingness to follow safety rules by signing the student safety pledge sheet.

SAFETY
UNIT II

SUGGESTED ACTIVITIES

Instructor:

I. Provide student with objective sheet.

II. Provide student with information and assignment sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information and assignment sheet(s).

VI. Discuss procedures for completing Student Safety Pledge Sheet.

VII. Ask local fire station to provide lecture and/or demonstration on fire safety, with emphasis on electrical fires.

VIII. Arrange for a course in first aid and cardiopulmonary resuscitation (CPR).

IX. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:
   A. Objective sheet
   B. Information sheet
   C. Transparency masters
      1. TM 1--Shocking Facts
      2. TM 2--Know Your Fire Extinguisher
      3. TM 3--Electrical Cord Danger Spots
   D. Assignment sheets
      1. Assignment Sheet #1--Test Your Knowledge About Electrical Shock
      2. Assignment Sheet #2--Test Your Knowledge About Safety Rules
      3. Assignment Sheet #3--Test Your Knowledge About Fire Safety
      4. Assignment Sheet #4--Plan and Execute a Class Fire Drill
      5. Assignment Sheet #5--Indicate a Willingness to Follow Safety Rules by Signing the Student Safety Pledge Sheet

E. Answers to assignment sheets

F. Test

G. Answers to test

II. References:

A. Grob, Bernard. *Basic Electronics.* New York: McGraw-Hill Book Co.

B. *New Mexico Vocational-Industrial Safety Guide.* Santa Fe, NM: New Mexico State Department of Education.

C. *Any Fire Traps?*, pamphlet, Greenfield, MA: Channing L. Bete., Inc.

SAFETY
UNIT II

INFORMATION SHEET

I. Terms and definitions

A. Safety--The state of being free from danger, personal risk, or injury

B. Accident--Any unplanned event, occurring suddenly, which causes personal injury or damage to property

C. First aid--Immediate care given to an accident or shock victim until medical help arrives

D. Electrical shock--The jolt a person experiences when electrical current passes through a part of the body

(NOTE: Electrical shock can cause serious burns and muscle damage, and can kill a victim by stopping the heart or breathing, or both.)

E. Electrical conductive materials--Materials through which electrical current flows easily

Examples: Copper, silver, gold, aluminum

F. Electrical insulating materials--Materials through which electrical current cannot flow easily

Examples: Rubber, cotton, wood

G. Electrical circuit--The system of wires and cables which carry electricity to motors, appliances, heating elements, and other devices which operate by means of electricity

H. Overloaded circuit--An electrical circuit which is drawing more electrical current than it is designed to handle

I. Electrical outlet adapter--An electrical plug which is installed into an electrical outlet to permit connecting two or more electrical wires or cables to the outlet

(NOTE: The adapter is called an "octopus" outlet if enough cables are attached to make the outlet look like a many-armed octopus.)

J. Fuse--A device which opens the circuit ("burns out") when the circuit is overloaded

K. Circuit breaker--A device which automatically opens the circuit like a switch if too much current is being drawn

L. Smoke alarm--A device which senses smoke and gives off a shrill sound to alert people in the area that a fire may be starting

INFORMATION SHEET

II. Hazards of working with electrical and electronics equipment

- A. Electrical shock

  (NOTE: Electrical shock can occur if the body contacts an electrical circuit or is struck by lightning.)

- B. Electrical burns

  (NOTE: Electrical burns can occur if the body contacts an electrical circuit or is struck by lightning, or if the body is exp[illegible] radio-frequency waves, X-rays, or other forms of radiation.)

- C. Electrical fires

  (NOTE: Electrical fires can occur if electrical wires become heated because of an overloaded circuit and contact flammable materials.)

- D. Injury from misuse of tools

  (NOTE: Body injuries can be caused by the improper use of tools.)

III. Facts about electrical shock (Transparency 1)

- A. Current is usually considered more dangerous than voltage
  1. High voltage (low current) tends to knock the victim away from the circuit, minimizing exposure time
  2. High current tends to cause the body to adhere to the circuit, so that the victim cannot let go
     - a. At about 1 milliampere (0.0010 amperes), a slight shock will be felt
     - b. At about 10 milliamperes (0.010 amperes) the shock is severe enough to paralyze muscles, but a person may be able to let go of the conductor
     - c. At about 100 milliamperes (0.1 amperes) the shock is usually fatal if it lasts for one second or more

       (NOTE: Human body resistance varies from about 500,000 ohms when dry to about 300 ohms when wet. Because of this, voltages as low as 30 volts can cause enough current to be fatal. Any circuit with a potential of at least 30 volts must be considered dangerous.)

INFORMATION SHEET

B. The frequency of alternating current can be dangerous

1. High frequency energy can cause serious body burns

   Examples: Radio-frequency (RF) waves

   Radar waves

   Microwaves (as in microwave ovens)

2. High frequency energy can arc from a conductor to the skin

3. Low frequency current, like 60 cycles per second, can be dangerous

IV. Treating a victim of electrical shock

A. Safely remove the victim from contact with the source of electricity using the following procedure:

(CAUTION: Do not touch the electrical circuit or the victim unless the power is off or you are insulated.)

1. Turn off the electricity by means of a switch or circuit breaker or cut cables or wires by means of a wood-handled axe or insulated cutters if available

2. Use a dry stick, rope, leather belt, coat, blanket, or any other nonconductor of electricity to separate the victim from the electrical circuit

B. Call for assistance

1. Others in the area may be more knowledgeable than you about treating the victim

2. Another person can call for professional medical help while you administer first aid

C. Check victim's breathing and heartbeat

(NOTE: TIME IS LIFE AT THIS POINT!)

1. If pulse is detectable, but breathing has stopped, administer mouth-to-mouth resuscitation until medical help arrives

2. If heartbeat has stopped, administer cardiopulmonary resuscitation, but only if you have been trained in the proper technique

   (CAUTION: Cardiopulmonary resuscitation can cause more harm than good to a victim unless the person administering the first aid has been trained in the proper procedure.)

INFORMATION SHEET

3. If both heartbeat and breathing have stopped, alternate between cardiopulmonary resuscitation and mouth-to-mouth resuscitation, but again, only if you have been trained in this technique

D. Administer first aid for shock and burns as necessary

1. Use blankets or coats to help keep the victim as warm and comfortable as possible while waiting for help

2. Raise victim's legs slightly above head level to help prevent shock

3. If the victim has suffered burns:

a. Cover your mouth and nostrils with gauze or a clean handkerchief to prevent breathing germs on the victim while treating the burns

b. Wrap burned area firmly with sterile gauze or clean linen or towels

(CAUTION: Do not attempt any other treatment of burns.)

E. Always continue treatment but only within your ability until medical help arrives

V. Types of fires

A. Class A--Fires that occur in ordinary combustible materials

Examples: Wood, rags, paper, or trash

B. Class B--Fires that occur in flammable liquids

Examples: Gasoline, oil, grease, paints, and thinners

C. Class C--Fires that occur in electrical and electronic equipment

Examples: Motors, switchboards, circuit wiring, radios, and television sets

D. Class D--Fires that occur in combustible metals

Examples: Powdered aluminum and magnesium

VI. Types of fire extinguishers and their use (Transparency 2)

A. Water types

1. All water types are used for class A fires only

2. Stored pressure--Operate by squeezing handle or turning valve

3. Cartridge operated--Operate by turning cylinder upside down and bumping

INFORMATION SHEET

   4. Water pump tank--Operate by pumping the handle

   5. Soda acid--Operate by turning cylinder upside down

  B. Foam type

   1. Use for class A or class B fires

   2. Operate by turning cylinder upside down

  C. Carbon dioxide type (CO_2)

   1. Use for class B or class C fires

   2. Operate by pulling pin and squeezing lever

  D. Dry chemical type

  (NOTE: This is a universal type.)

   1. Use for class B or class C fires

   2. Operate by pulling pin or rupturing cartridge and squeezing lever

   (NOTE: Fire extinguishers are not effective for class D fires. Instead, smother metal fires with dry sand, dirt, salt, or soda ash.)

VII. Safety color coding

  A. Green

   1. Applied to nonhazardous parts of machine and equipment surfaces, like nameplates and bearing surfaces

   2. Designates safe areas of equipment, and is also used to show location of safety equipment and first-aid materials

  B. Yellow

   1. Applied to operating levers, wheels, handles, and hazardous parts that may cause stumbling, falling, snagging, or tripping

   2. Designates caution

  C. Orange

   1. Applied to electrical switches, interior surfaces of doors, fuses and electrical power boxes, and movable guards and parts

   2. Indicates dangerous parts of equipment which may cut, crush, shock, or otherwise physically injure someone

INFORMATION SHEET

D. Red

1. Applied to buttons or levers of electrical switches used for stopping machinery, and to all equipment, such as gasoline cans, which are fire hazards

2. Designates fire hazards and fire-fighting equipment

(NOTE: The color red is also applied to other fire-fighting equipment, such as fire alarms, fire axes, and emergency exits.)

E. Blue

1. Used to identify equipment which is being repaired or is defective and should not be operated

2. Designates "out of order" or "defective"

F. Ivory

1. Applied to label edges, vise jaws, and edges of tool rests where extra light reflection is important

2. No particular designation except to help show tool and equipment moving edges more clearly

VIII. General lab safety rules

A. Keep all hand tools clean and in safe working order

B. Report any defective tools, test equipment, or other equipment to the instructor

C. Do not remove any safety devices, (i.e. ground straps, switch covers, etc.) without the permission of the instructor

D. Do not operate or energize any circuit that could be hazardous without first receiving instruction on how to do so safely

E. Report all accidents to the instructor regardless of nature or severity

F. Turn off power before leaving test equipment or circuits being worked on

G. Do not use any solvent without first determining its properties, and how to use it safely

(NOTE: Solvents should be used only in well-ventilated spaces.)

H. Keep the laboratory floor clean of scraps and litter

INFORMATION SHEET

I. Clean up any spilled liquids immediately

J. Store all cleaning rags in metal cans or containers

(NOTE: Cleaning rags could contain oil.)

IX. Personal safety rules

A. When working on or near rotating machinery, secure loose clothing and tie hair (if long)

B. Isolate line (power) voltages from ground by means of isolation transformers

C. Check all line (power) cords before using and if the insulation is brittle and/or cracked, DO NOT USE and report to the instructor

D. When measuring voltages with a meter and test probe, be careful not to connect yourself to a voltage of any value

E. Be certain that floor is insulated either by tile, rubber mats, or the wearing of rubber-soled shoes

F. When measuring voltages expected to be greater than 30 volts, turn off or disconnect live circuit before connecting test equipment

(NOTE: Treat voltages of 30 volts or over with great respect.)

G. It is recommended that only equipment with a polarized (3-prong) plug be used

H. Do not defeat the purpose of any safety device such as fuses, circuit breakers, or interlocks; shorting across these devices could cause excessive current flow, and destroy or seriously damage equipment being worked on, as well as cause a fire

I. Do not carry sharp-edged or pointed tools in your pockets

J. Do not indulge in horseplay or play practical jokes in any work area

K. Wear gloves and goggles when required

L. Do not wear rings or jewelry when working with mechanical or electrical devices

M. Exercise good judgment and common sense

X. Hand tool safety precautions

(NOTE: Electronic technicians are required to use hand tools and power tools to build the mechanical parts of electronic equipment. Many accidents are caused by the thoughtless use of tools. Thoughtless use of tools includes using a tool carelessly or incorrectly. Accidents result from using a tool to do something for which it was not intended. There is a right way and a wrong way to use any tool. Learn to use tools in the right way.)

INFORMATION SHEET

A. Keep tools in proper working condition

B. Always put a handle on a file when you use it

C. Use caution with your soldering iron or gun; they can burn and cause fires

D. Exercise care in using long nose pliers and diagonal cutters; they can pinch and cut

E. Do not use long nose pliers as a wrench

F. Ease up on the pressure just before a hacksaw completes its cut

(NOTE: Many knuckles and hands have been cut because this was forgotten.)

G. Whenever possible, pull on a wrench; don't push

H. Be sure hammer heads and screwdriver blades are fastened tightly in their handles

I. Use safety glasses or goggles when soldering or unsoldering

XI. Power tool safety precautions

(NOTE: Power tools usually operate on 120 volts. This voltage can cause serious shock, burns, or under certain conditions death. Always check the power tool before you use it. Be sure the cord is in good condition and that the plug and switch are not broken.)

A. Keep the cord clear of the work

B. When drilling, use a sharp drill bit; pressure on a dull drill bit can cause an accident

C. Securely fasten the work being drilled

(NOTE: The drill will turn both the bit and the work which can cause injury.)

D. Be sure your hands are dry before using electric tools

E. Keep power tool guards in place; they are for your protection

F. Operate power tools only after you have had instruction in their uses

G. Wear safety goggles or glasses when operating power tools

(NOTE: Flying chips can cause permanent damage to your eyes.)

H. Power cords and switches should be checked before using a power tool

INFORMATION SHEET

XII. Electrical cord safety rules (Transparency 3)

A. Do not overload a circuit by connecting numerous cords to a single outlet by means of "octopus" adapters

B. Do not pull the cord to disconnect; use the plug

C. Do not use electrical cords with frayed or worn insulation; replace cord as necessary

D. Do not suspend electrical cords over nails or pipes

E. Never run electrical cords:

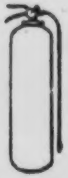
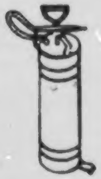
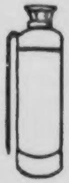
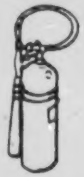
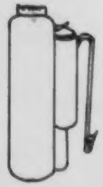
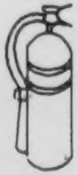
1. Near heating devices, like space heaters or radiators
2. Across walkways
3. Under carpets or rugs
4. Through door jambs

Shocking Facts

60-Hertz Current Values Affecting Human Beings

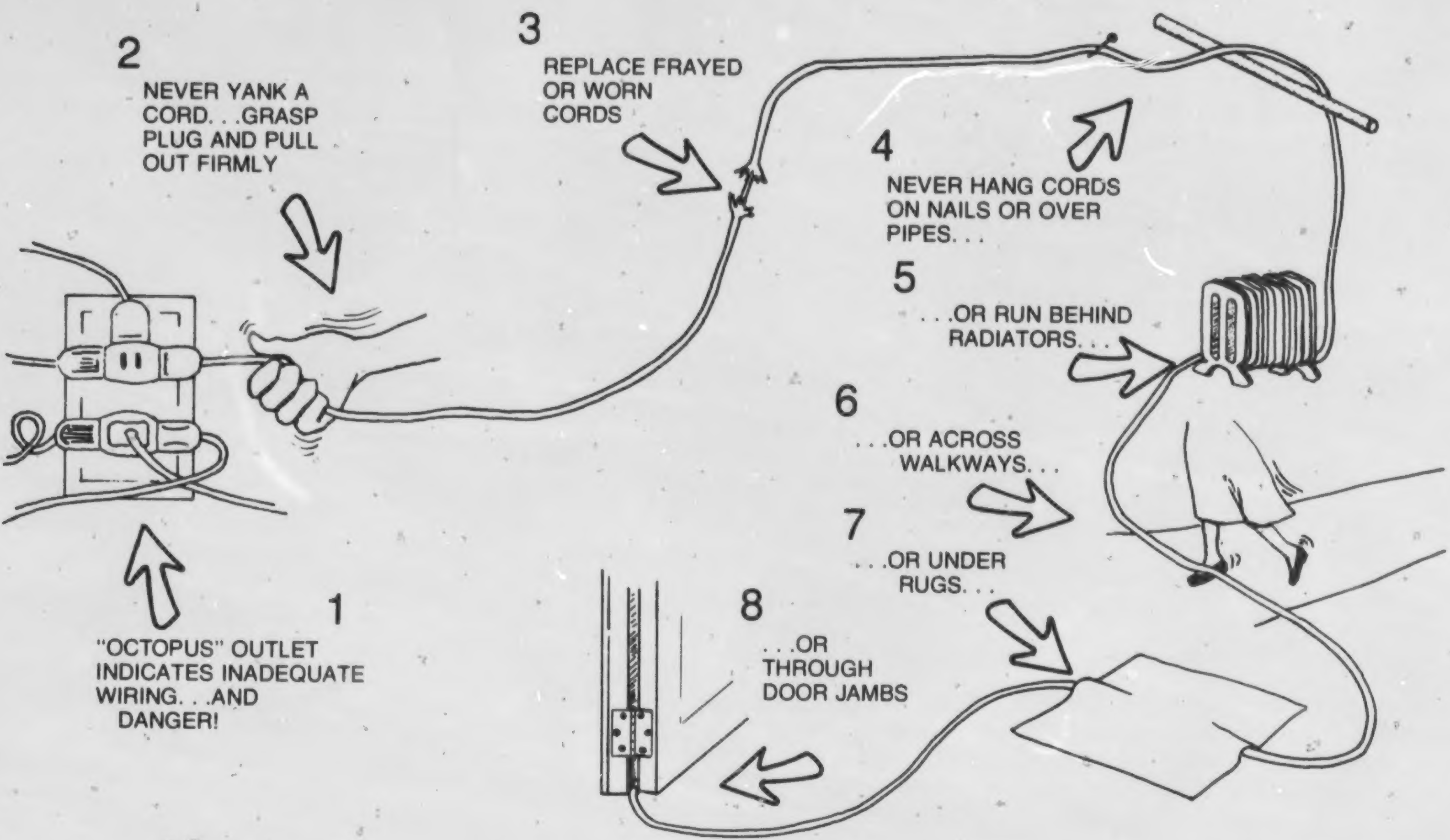
CURRENT VALUE		EFFECTS
1 ma	(.001 amperes)	Mild sensation (tingle).
10 ma	(.010 amperes)	Shock is of sufficient intensity to prevent voluntary control of muscles, so that you will not be able to let go of conductor.
100 ma	(.100 amperes)	Shock obtained at 100 milliamperes for one second is sufficient to be fatal.
Over 100 ma		Same as above, only more severe. A heart condition known as ventricular fibrillation may occur. A change in rhythm of the heart beat, causing death almost immediately.

KNOW YOUR FIRE EXTINGUISHER

	WATER TYPE				FOAM	CARBON DIOXIDE	DRY CHEMICAL	
TYPE EXTINGUISHER	 STORED PRESSURE	 CARTRIDGE OPERATED	 WATER PUMP TANK	 SODA ACID	 FOAM	 CO2	 CARTRIDGE OPERATED	 STORED PRESSURE
TYPES OF FIRES								
CLASS A: WOOD, PAPER, TRASH HAVING GLOWING EMBERS	YES	YES	YES	YES	YES	NO	NO	NO
CLASS B: FLAMMABLE LIQUIDS, GASOLINE, OIL, PAINT GREASE, ETC.	NO	NO	NO	NO	YES	YES	YES	YES
CLASS C: ELECTRICAL EQUIPMENT	NO	NO	NO	NO	NO	YES	YES	YES
CLASS D: COMBUSTIBLE METALS	*	*	*	*	*	*	*	*
METHOD OF OPERATION	SQUEEZE HANDLE OR TURN VALVE	TURN UPSIDE DOWN AND BUMP	PUMP HANDLE	TURN UPSIDE DOWN	TURN UPSIDE DOWN	PULL PIN, SQUEEZE LEVER	RUPTURE CARTRIDGE, SQUEEZE LEVER	PULL PIN, SQUEEZE LEVER

* DO NOT USE FIRE EXTINGUISHER. SMOTHER FIRE WITH DRY SAND, GRAPHITE, DIRT, OR SODA ASH.

Electrical Cord Danger Spots



1

"OCTOPUS" OUTLET INDICATES INADEQUATE WIRING. . .AND DANGER!

2

NEVER YANK A CORD. . .GRASP PLUG AND PULL OUT FIRMLY

3

REPLACE FRAYED OR WORN CORDS

4

NEVER HANG CORDS ON NAILS OR OVER PIPES. . .

5

. . .OR RUN BEHIND RADIATORS. . .

6

. . .OR ACROSS WALKWAYS. . .

7

. . .OR UNDER RUGS. . .

8

. . .OR THROUGH DOOR JAMBS

SAFETY
UNIT II

ASSIGNMENT SHEET #1--TEST YOUR KNOWLEDGE ABOUT ELECTRICAL SHOCK

a. Match the terms on the right with the proper definitions. Answers may be used more than once.

_____1. 0.1 ampere

_____2. Unplanned event

_____3. Emergency care

_____4. Being free from danger

_____5. Heart or breathing stopped

_____6. Muscle paralysis

_____7. Just feeling a shock

_____8. Jarring, shaking feeling

_____9. Event involvng personal injury

_____10. Unable to let go

_____11. Fatal if more than one second

a. Safety

b. First aid

c. Accident

d. Electric shock

e. 1 milliampere

f. 10 milliamperes

g. 100 milliamperes

h. Death

b. At about _____ amperes the shock is usually fatal if it lasts for one second or more.

c. It has been found that the human body resistance to electrical current varies from about _____ ohms wet to _____ ohms dry.

_____1. 30 - 500,000

_____2. 300 - 500,000

_____3. 300,000 - 500,000

_____4. 500,000 - 30

d. Because of the varying body resistance to electrical current, any circuit with a potential of at least _____ volts MUST BE CONSIDERED DANGEROUS.

_____1. 300

_____2. 3,000

_____3. 30

_____4. 30,000

e. List at least two ways to remove a victim from contact with an electrical circuit.

1. ____

2. ____

SAFETY
UNIT II

ASSIGNMENT SHEET #2--TEST YOUR KNOWLEDGE ABOUT SAFETY RULES

a. From the list of conditions listed below, select the conditions that are unsafe and safe by placing an "X" in the appropriate columns.

Conditions:	Unsafe	Safe
1. Oily rags on floor	______	____
2. Soldering iron on stand	______	____
3. Line cord insulation frayed	______	____
4. Equipment isolated by transformer	______	____
5. Litter on floor	______	____
6. One hand behind back	______	____

b. If you noticed that a line cord was frayed which of the following would be the best thing for you to do?

______1. Notify the instructor or supervisor

______2. Unplug it from the wall

______3. Repair it or replace it

______4. All of the above are correct

c. Which of the following currents would be fatal to the human body if applied for one second or more?

______1. 0.1 ampere

______2. 0.01 ampere

______3. 0.001 ampere

______4. 0.0001 ampere

d. If your friend was being shocked, and you couldn't find the switch, nor find anything to pull him off with, which of the following could you use to cut the wires?

______1. A kitchen knife

______2. A power saw

______3. Diagonal cutters

______4. A fire axe

e. If you are in a shop area and a fire suddenly occurred, which of the following colors would help you to locate the fire extinguisher?

______1. Yellow

______2. Red

______3. Green

______4. Orange

ASSIGNMENT SHEET #2

f. When working with electrical test equipment you should be certain that the _____ is turned off before you leave it for any reason.

_____1. Lights _____3. Power

_____2. Water _____4. Sound

g. If you have, or see anyone else have an accident, you should immediately:

_____1. Report it to the supervisor _____3. Turn your back

_____2. Call the principal _____4. Correct the condition that caused it

h. List six general safety rules that apply to lab sessions.

1. ______________________________
2. ______________________________
3. ______________________________
4. ______________________________
5. ______________________________
6. ______________________________

i. List six specific (personal) safety rules that apply to the student during lab sessions.

1. ______________________________
2. ______________________________
3. ______________________________
4. ______________________________
5. ______________________________
6. ______________________________

j. At about _______________ an electric shock is severe enough to cause muscle paralysis.

_____1. 1 milliampere

_____2. 10 milliamperes

_____3. 100 milliamperes

_____4. 1,000 milliamperes

k. List a safety rule to be followed when working with the following hand tools.

1. Files
2. Soldering iron when soldering
3. Diagonal pliers
4. Long nose pliers
5. Hacksaw
6. Hammer
7. Soldering iron when unsoldering

l. List eight specific safety rules that apply when using power tools.

1. ____________________
2. ____________________
3. ____________________
4. ____________________
5. ____________________
6. ____________________
7. ____________________
8. ____________________

m. List the one safety precaution you should always observe when operating any kind of power tool.

SAFETY
UNIT II

ASSIGNMENT SHEET #3--TEST YOUR KNOWLEDGE ABOUT FIRE SAFETY

a. Match the terms on the right to the correct spaces. Answers may be used more than once.

______1. Switchboard fire
______2. Wood fire
______3. Oil fire
______4. Must be turned upside down
______5. Most commonly used
______6. Do NOT use on Class B or C
______7. Contains only water
______8. Carbon dioxide
______9. Paper fire
______10. Use on flammable liquids
______11. Combustive metal fire

a. Class A
b. Class B
c. Class C
d. Pressurized water
e. Foam
f. CO_2
g. Soda acid
h. Dry chemical (universal type)
i. Class D

b. The class of fire that you would most normally find to occur in an electronics lab would be:

______1. Class A
______2. Class B
______3. Class C
______4. Class F
______5. Class D
______6. Class I

c. In order to extinguish a class A fire you would probably use the following:

______1. Pressurized water
______2. Soda acid
______3. Foam
______4. All of the above

d. In an electrical fire you should never use which of the following:

______1. Carbon dioxide
______2. Pressurized water
______3. Dry chemical
______4. None of the above

e. Which of the following types of extinguishers usually must be turned upside down before they can be used?

______1. CO_2
______2. Dry chemical and water
______3. Pressurized water and foam
______4. Soda acid and foam

SAFETY
UNIT II

ASSIGNMENT SHEET #4--PLAN AND EXECUTE A CLASS FIRE DRILL

a. Determine five areas in your classroom or school workshop where fires could start.

b. Plan a safe exit route away from each of the possible fires.

c. Locate the nearest fire alarm; make sure you know how to operate it.

d. Locate the nearest telephone. Find out what the fire emergency dial numbers are or how to dial the operator.

e. Practice giving location directions for the fire over the telephone.

f. Locate fire extinguishers which are closest to the possible fires determined in step a. Refer to Transparency 2 and check:

    1. Type of extinguisher
    2. Type of fires it is used on
    3. How to operate it

g. Determine which fire extinguisher should be used for each of the possible fires determined in step a.

h. Appoint a fire marshall from among class members. This person will:

    1. Alert the class regarding the fire (simulated)
    2. Point out the safest exit route
    3. Operate the fire alarm or call the fire department
    4. Man the proper fire extinguisher
    5. Direct firemen to the fire when they arrive

i. Conduct a practice fire drill based on the above procedures.

SAFETY
UNIT II

ASSIGNMENT SHEET #5--INDICATE A WILLINGNESS TO FOLLOW SAFETY RULES BY SIGNING THE STUDENT SAFETY PLEDGE SHEET

STUDENT SAFETY PLEDGE SHEET

________________ ________________ ____________________

who is enrolled in Vocational Electronics Program, will as a part of his or her shop experience, operate both test equipment and electrical and/or electronics equipment, providing that his or her parent or guardian gives written permission, if applicable.

It is understood that each student will be given proper instruction both in the use of the equipment and in correct safety procedures concerning it, before being allowed to operate it himself or herself. The student must assume responsibility for following safe practices, and we therefore ask that he or she subscribe to the following:

1. To follow all safety rules for the shop.
2. Never to use a piece of equipment without first having permission from the instructor.
3. Not to ask permission to use a particular piece of equipment unless I have been instructed in its use, and have 100% on the safety test for that equipment.
4. To report any accident or injury to the teacher immediately.

I subscribe to the above:

DATE ____________ STUDENT'S SIGNATURE ______________________

I hereby give my consent to allow my son/daughter to operate all tools and equipment necessary in carrying out the requirements of the course in which he/she is enrolled.

DATE ____________ PARENT'S SIGNATURE ______________________
(If applicable)

Parents are cordially invited to visit the shop to inspect the equipment and observe it in operation.

SAFETY
UNIT II

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

a. 1. g
   2. c
   3. b
   4. a
   5. h
   6. f
   7. e
   8. d
   9. c
   10. f
   11. g

b. 0.1 ampere

c. 2

d. 3

e. 1. Pull off with belt, coat, blanket or any nonconductor
   2. Open switch to circuit

f. 1. Electric shock
   2. Electrical fires
   3. Gases

Assignment Sheet #2

a. 1. Unsafe
   2. Safe
   3. Unsafe
   4. Safe
   5. Unsafe
   6. Safe

b. 1

c. 1

d. 4

e. 2

f. 3

g. 1

h. Any six of the following:

1. Keep all hand tools clean and in safe working order
2. Report any defective tools, test equipment, or other equipment to the instructor
3. Do not remove any safety devices, (i.e. ground straps, switch covers, etc.) without the permission of the instructor
4. Do not operate or energize any circuit that could be hazardous without first receiving instruction on how to do so safely
5. Report all accidents to the instructor regardless of nature or severity
6. Turn off power before leaving test equipment or circuits being worked on
7. Do not use any solvent without first determining its properties, and how to use it safely
8. Keep the laboratory floor clean of scraps and litter
9. Clean up any spilled liquids immediately
10. Store all cleaning rags in metal cans or containers

i. Any six of the following:

1. When working on or near rotating machinery, secure loose clothing and tie hair (if long)
2. Isolate line (power) voltages from ground by means of isolation transformers
3. Check all line (power) cords before using and if the insulation is brittle and/or cracked, DO NOT USE and report to the instructor
4. When measuring voltages with a meter and test probe, be careful not to connect yourself to a voltage of any value
5. Be certain that floor is insulated either by tile, rubber mats, or the wearing of rubber-soled shoes
6. When measuring voltages expected to be greater than 30 volts, turn off or disconnect live circuit before connecting test equipment
7. It is recommended that only equipment with a polarized (3-prong) plug be used
8. Do not defeat the purpose of any safety device such as fuses, circuit breakers, or interlocks; shorting across these devices could cause excessive current flow, and destroy or seriously damage equipment being worked on, as well as cause a fire

9. Do not carry sharp-edged or pointed tools in your pockets
10. Do not indulge in horseplay or play practical jokes in any lab
11. Wear gloves and goggles when required
12. Do not wear rings or jewelry when working with mechanical or electrical devices
13. Exercise good judgment and common sense

j. 2

k. 1. Always put a handle on a file when you use it
2. Use caution with your soldering iron or gun; they can burn and cause fires
3. Exercise care in using long nose pliers and diagonal cutters; they can pinch and cut
4. Do not use long nose pliers as a wrench
5. Ease up on the pressure just before a hacksaw completes its cut
6. Be sure hammer head is fastened tightly in its handle
7. Use safety glasses or goggles when soldering or unsoldering

l. 1. Keep the cord clear of the work
2. When drilling, use a sharp drill bit; pressure on a dull drill bit can cause an accident
3. Securely fasten the work being drilled
4. Be sure your hands are dry before using electric tools
5. Keep power tool guards in place; they are for your protection
6. Operate power tools only after you have had instruction in their uses
7. Wear safety goggles or glasses when operating power tools
8. Power cords and switches should be checked before using a power tool

m. Wear your safety glasses or goggles

Assignment Sheet #3

a. 1. c
2. a
3. b

4. e and g
5. f
6. d
7. d
8. b, c, and f
9. a, c, and d
10. h
11. i

b. 3

c. 4

d. 2

e. 4

BE - 57-A

SAFETY
UNIT II

NAME ______________________________

TEST

1. Match the terms on the right to the correct definitions.

______a. The state of being free from danger, personal risk, or injury

______b. Any unplanned event, occurring suddenly, which causes personal injury or damage to property

______c. Immediate care given to an accident or shock victim until medical help arrives

______d. The jolt a person experiences when electrical current passes through a part of the body

______e. Materials through which electrical current flows easily

______f. Materials through which electrical current cannot flow easily

______g. The system of wires and cables which carry electricity to motors, appliances, heating elements, and other devices which operate by means of electricity

______h. An electrical circuit which is drawing more electrical current than it is designed to handle

______i. An electrical plug which is installed into an electrical outlet to permit connecting two or more electrical wires or cables to the outlets

______j. A device which opens the circuit when the circuit is overloaded

______k. A device which automatically opens a circuit like a switch if too much current is being drawn

______l. A device which senses smoke and gives off a shrill sound to alert people in the area that a fire may be starting

1. Fuse
2. First aid
3. Electrical conductive materials
4. Overloaded circuit
5. Safety
6. Smoke alarm
7. Circuit breaker
8. Accident
9. Electrical outlet adapter
10. Electrical shock
11. Electrical circuit
12. Electrical insulating materials

2. Name four hazards of working with electrical or electronic equipment.

   a. ______________________________

   b. ______________________________

   c. ______________________________

   d. ______________________________

3. Select true statements concerning electrical shock by placing an "X" in the appropriate spaces.

   ______a. Electrical shock can hurt, but it can't kill

   ______b. One cannot feel electrical shock

   ______c. Current is usually considered more dangerous than voltage

   ______d. High current tends to cause the body to adhere to the circuit, so that the victim cannot let go

   ______e. At about 10 milliamperes (0.010 amperes) the shock is severe enough to paralyze muscles, but a person may be able to let go of the conductor

   ______f. At about 100 milliamperes (0.1 amperes) the shock is usually fatal if it lasts for one second or more

   ______g. The frequency of alternating current is not a factor in electrical shock

   ______h. Low frequency current, like 60 cycles per second, can be dangerous

4. Select the statements that describe correct procedures in treating a victim of electrical shock by placing an "X" in the appropriate blanks.

   ______a. Cut the electrical conductor by means of ordinary metal tin snips to remove current from the victim

   ______b. Use a dry stick, leather belt, rope, blanket, coat, or any other nonconductor of electricity to separate the victim from the electrical circuit

   ______c. Do not call for assistance--this may cause too large a crowd to gather

   ______d. Always assume that you know more than anyone else about how to treat the victim

   ______e. If heartbeat has stopped, administer cardiopulmonary resuscitation, but only if you have been trained in the proper technique

   ______f. Mouth-to-mouth resuscitation should never be attempted

   ______g. Use blankets or coats to help keep the victim as warm and comfortable as possible while waiting for help

   ______h. Raise victim's head slightly above leg level to help prevent shock ______i. If victim has suffered burns, apply butter or grease to burned areas

______j. Always continue treatment but only within your ability until medical help arrives

______k. When treating burns, cover your mouth and nostrils with gauze or a clean handkerchief to prevent breathing germs on the victim while treating the burns

5. Match the types of fires described below with the proper class on the right.

______a. Fires that occur in ordinary combustible materials

______b. Fires that occur in electrical and electronic equipment

______c. Fires that occur in combustible metals

______d. Fires that occur in flammable liquids

1. Class C
2. Class A
3. Class D
4. Class B

6. For each type of fire extinguisher listed below, state the class of fire it is used for and how it is operated.

a. Water type--Stored pressure

1) Use for Class ______ fires

2) Operate by ______________________________

b. Foam type

1) Use for Class ______ fires

2) Operate by ______________________________

c. Carbon dioxide type (CO_2)

1) Use for Class ______ fires

2) Operate by ______________________________

d. Dry chemical type (universal type)

1) Use for Class ______ fires

2) Operate by ______________________________

7. Match the color codes on the right to the type of hazard they designate.

______a. Operating levers, wheels, handles, and other hazardous parts which could cause falling, snagging, or tripping

______b. Fire hazards and fire-fighting equipment

______c. Nonhazardous parts of machines and equipment surfaces

1. Blue
2. Yellow
3. Red
4. Orange
5. Ivory
6. Green

_____d. Equipment which is being repaired or is defective and should not be operated

_____e. Label edges, vise jaws, and edges of tool rests where extra light reflection is important

_____f. Electrical switches, interior surfaces of doors, fuses and electrical power boxes, and movable guards and parts

8. Select the statements which describe good general lab safety rules by placing an "X" in the appropriate blanks.

_____a. Keep all hand tools clean and in safe working order

_____b. Do not remove any safety devices (i.e., ground straps, switch covers, etc.) without the permission of the instructor

_____c. Do not operate or energize any circuit that could be hazardous without first receiving instruction on how to do so safely

_____d. Report all accidents to the instructor regardless of nature or severity

_____e. Do not use any solvent without first determining its properties, and how to use it safely

_____f. Keep the laboratory floor clean of scraps and litter

_____g. Store all cleaning rags in metal cans or containers

_____h. Report any defective tools, test equipment or other equipment to the instructor

_____i. Turn off power before leaving test equipment or circuits being worked on

_____j. Clean up any spilled liquids immediately

_____k. Do electrical experiments in the dark

_____l. Wear long hair so that people can pull you to safety more easily

9. Select the statements which are good personal safety rules by placing an "X" in the appropriate blanks.

_____a. When working on or near rotating machinery, secure loose clothing and tie hair (if long)

_____b. Check all line (power) cords before using and if the insulation is brittle and/or cracked, DO NOT USE and report to the instructor ______c. Be certain that floor is insulated either by tile, rubber mats, or the wearing of rubber-soled shoes

______d. It is recommended that only equipment with a polarized (3-prong) plug be used

______e. Do not carry sharp-edged or pointed tools in your pockets

______f. Wear gloves and goggles when required

______g. Exercise good judgment and common sense

______h. Do not indulge in horseplay or play practical jokes in any work area

______i. Do not defeat the purpose of any safety devices such as fuses, circuit breakers, or interlocks; shorting across these devices could cause excessive current flow, and destroy or seriously damage equipment being worked on, as well as cause a fire

______j. When measuring voltages expected to be greater than 30 volts, turn off or disconnect live circuit before connecting test equipment

______k. When measuring voltages with a meter and test probe, be careful not to connect yourself to a voltage of any value

______l. Isolate line (power) voltages from ground by means of an isolation transformer

______m. Keep hands wet when doing electrical experiments

______n. Don't ever put your hand in your pocket

10. Select the safety rules which describe hand tool safety precautions by placing an "X" in the appropriate blanks.

______a. A large screwdriver can be used as a pry-bar

______b. Always put a handle on a file when you use it

______c. Whenever possible push on a wrench, don't pull on it

______d. Do not use long nose pliers as a wrench

______e. Use safety glasses or goggles when soldering or unsoldering

______f. The use of hand tools is obvious - you don't need any instructions

______g. The use of hand tools seldom causes accidents

11. Select the safety rules which describe power tool safety precautions by placing an "X" in the appropriate blanks.

______a. A dull drill bit can be used if you apply sufficient pressure

______b. Securely fasten the work being drilled

______c. It is correct to use a hand drill even though your hands are wet with perspiration _____d. Power tool guards can be removed if they interfere with your work

_____e. Wear safety goggles or glasses when operating power tools

_____f. Power cords and switches should be checked before using a power tool

12. Select the statements that describe rules for safe use of electrical cords by placing an "X" in the appropriate blanks.

_____a. Do not overload a circuit by connecting numerous cords to a single outlet by means of "octopus" adapters

_____b. Disconnect electrical cables by pulling on the cord

_____c. Repair frayed or worn cords with cellophane tape

_____d. Do not suspend electrical cords over nails or pipes

_____e. Electrical cords can be routed under rugs to prevent people from tripping over them

_____f. Never run electrical cords through door jambs

13. Properly plan and execute a class fire drill.

14. Indicate a willingness to follow safety rules by signing the student safety pledge sheet.

(NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

SAFETY
UNIT II

ANSWERS TO TEST

1. a. 5 c. 2 e. 3 g. 11 i. 9 k. 7
   b. 8 d. 10 f. 12 h. 4 j. 1 l. 6

2. a. Electrical shock
   b. Electrical burns
   c. Electrical fires
   d. Injury from misuse of tools

3. c, d, e, f, h

4. b, e, g, j, k

5. a. 2 c. 3
   b. 1 d. 4

6. a. 1) Class A
      2) Squeezing handle or turning valve

   b. 1) Class A or B
      2) Turning cylinder upside down

   c. 1) Class B or C
      2) Pulling pin and squeezing lever

   d. 1) Class B or C
      2) Pulling pin or rupturing cartridge and squeezing lever

7. a. 2 c. 6 e. 5
   b. 3 d. 1 f. 4

8. a, b, c, d, e, f, g, h, i, j

9. a, b, c, d, e, f, g, h, i, j, k, l

10. b, d, e

11. b, e, f

12. a, d, f

13. Evaluated to the satisfaction of the instructor.

14. Evaluated to the satisfaction of the instructor.

HAND TOOLS
UNIT III

UNIT OBJECTIVE

After completion of this unit, the student should be able to identify basic hand tools and list maintenance procedures for tools. The student should also be able to clean and lubricate pliers and adjust wire strippers. This knowledge will be evidenced by correctly performing the procedures outlined on the job sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Identify basic hand tools.
2. Match tools to their uses.
3. List factors to consider when selecting tools.
4. List maintenance procedures for tools.
5. Demonstrate the ability to:
    a. Clean and lubricate pliers.
    b. Adjust wire strippers.

HAND TOOLS
UNIT III

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information and job sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information sheets.

VI. Demonstrate and discuss the procedures outlined in the job sheets.

VII. Encourage all students to get actual hands-on experience with all the hand tools available at your location.

VIII. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:
  A. Objective sheet
  B. Information sheet
  C. Transparency masters
    1. TM 1--Hand Tools
    2. TM 2--Hand Tools (Continued)
    3. TM 3--Hand Tools (Continued)
  D. Job sheets
    1. Job Sheet #1--Clean and Lubricate Pliers
    2. Job Sheet #2--Adjust Wire Strippers
  E. Test
  F. Answers to test

II. References:
  A. *Residential Wiring.* Stillwater, OK: Mid-America Vocational Curriculum Consortium/Oklahoma State Department of Vocational and Technical Education, 1978.

B. *Basic Electricity/Electronics.* Natchitoches, LA: State Department of Vocational Education, 1979.

III. Additional Materials--*Tools and Test Instruments for Technicians.* Englewood, CO 80110: National Camera, Inc.

HAND TOOLS
UNIT III

INFORMATION SHEET

I. Types of hand tools (Transparencies 1, 2, and 3)

   A. Pliers

      1. Long nose chain pliers

         (NOTE: These are sometimes called needlenose pliers.)

      2. Diagonal cutting pliers

      3. Lineman's side cutting pliers

      4. Combination slip joint pliers

   B. Screwdrivers

      1. Flat blade (slot-head) screwdriver

      2. Phillips head (cross-point) screwdriver

   C. Saws

      1. Hacksaw

      2. Hole saw

   D. Adjustable wire strippers

   E. Electrician's six-in-one tool

   F. Wrenches

      1. Adjustable wrench

      2. Hex and spline wrench

   G. Nut driver

   H. Drill and drill bits

   I. Wire gauge

   J. Hemostat clamp

   K. Ball peen hammer

INFORMATION SHEET

- L. Files
  - 1. Flat file
  - 2. Half-round file
  - 3. Precision file
- M. Punches
  - 1. Center punch
  - 2. Square hole punch
  - 3. Round hole punch

II. Tools and their uses

- A. Long nose chain pliers
  - 1. Holding components
  - 2. Heat sink
  - 3. Shaping and forming small conductors
- B. Diagonal cutting pliers
  - 1. Cutting wire and component leads
  - 2. Stripping insulation from wire
- C. Lineman's side cutting pliers
  - 1. Cutting heavier conductors and cables
  - 2. Cutting small screws
  - 3. Stripping insulation from wires
  - 4. Forming large conductors
- D. Combination slip joint pliers
  - 1. Loosening small to medium size nuts and bolts
  - 2. Holding and turning
- E. Screwdrivers--Removing or tightening screws and bolts (flat blade or Phillips)

INFORMATION SHEET

F. Hacksaw

  1. Cutting chassis metal

  2. Cutting bolts or metal parts

     Example: Antenna installation parts, or screws and bolts too large to cut with side cutting pliers

G. Electrician's six-in-one tool

  1. Crimping solderless connections

  2. Cutting wire

  3. Stripping insulation from wire

  4. Shearing bolts

  5. Thread gauges

  6. Length gauges for stripping

H. Nut drivers

  1. Holding nuts or bolt heads

  2. Tightening or loosening nuts or bolts

I. Hex and spline wrenches

  1. Tightening or loosening socket cap screws

  2. Tightening or loosening set screws

J. Hole saws and hole punches

  1. Cutting holes up to four inches in diameter

  2. Punching round or square holes in metal

III. Factors to consider when selecting tools

A. Tool size should be matched to the work most frequently encountered

B. Tools should be specifically designed for electronic use when possible

  1. Should have insulation on handles of pliers

  2. Should have insulation on handles of screwdrivers

C. Purchasing quality tools is less expensive in the long run

INFORMATION SHEET

D. Know the specifications before purchasing a tool

(NOTE: When in doubt about what tools are best, consult a practicing electronics specialist in your area.)

Example: Pliers, long chain nose, 5'', with plastic grip handles, and serrated jaws

Flat blade screwdriver, electrician's round shank, 6" x 3/16" blade w/cushion grips

IV. Tool maintenance procedures

A. Screwdrivers

1. Regrind worn or damaged flat blade screwdrivers
2. Discard damaged Phillips screwdrivers

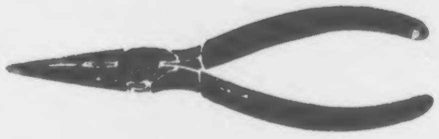
B. Pliers

1. Keep pliers clean and rust free
2. Keep cutting edges sharp and smooth
3. Keep pliers working freely
4. Repair or replace damaged handle insulation

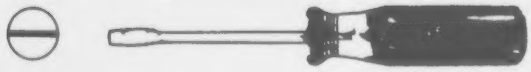
C. Adjustable wrenches--Keep worm gears clean and lubricated

D. All tools--Identify tools by labeling with an electric vibrator pen or scratch awl

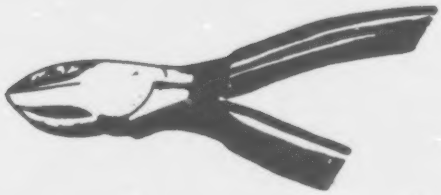
Hand Tools



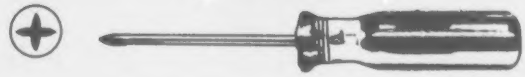
Long Nose Chain Pliers



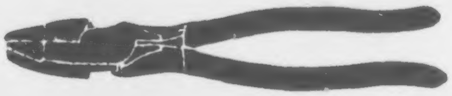
Flat Blade (slot-head) Screwdriver



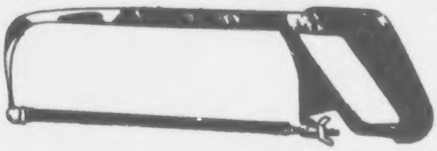
Diagonal Cutting Pliers



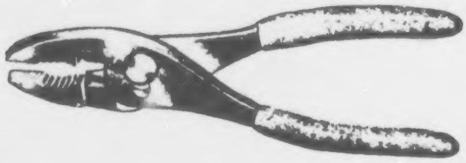
Phillips Head Screwdriver



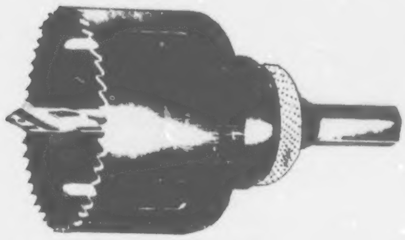
Lineman's Side Cutting Pliers



Hacksaw

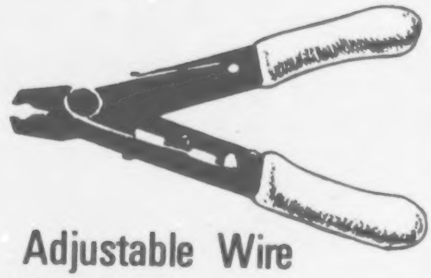


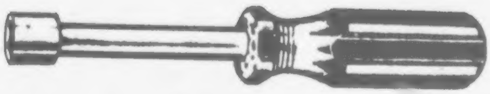
Combination Slip-Joint Pliers

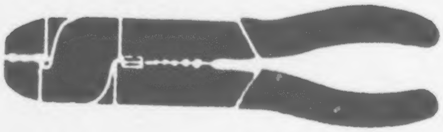


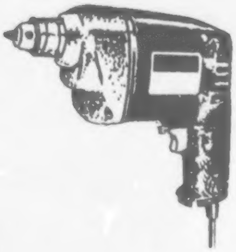
Hole Saw

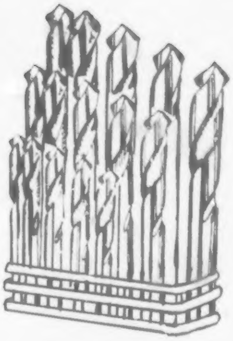
Hand Tools
(Continued)

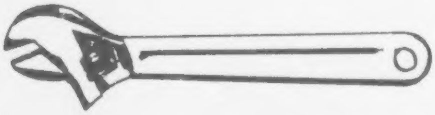

Adjustable Wire Strippers

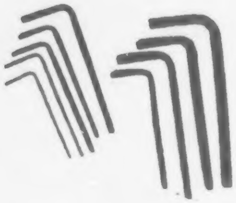

Nut Driver

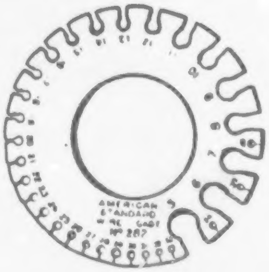

Electrician's Six-in-One Tool

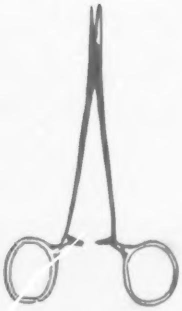

Drill


Drill Bits

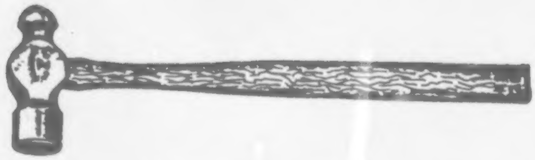

Adjustable Wrench


Hex and Spline Wrenches


AMERICAN
STANDARD
WIRE GAGE
No 287
Wire Gauge

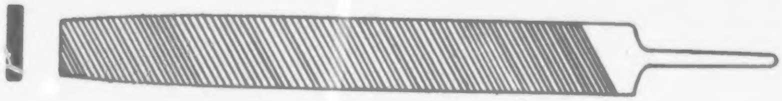

Hemostat Clamp

Hand Tools
(Continued)



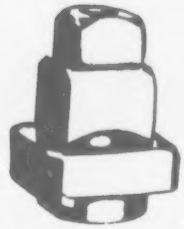
Ball Peen Hammer

Center Punch

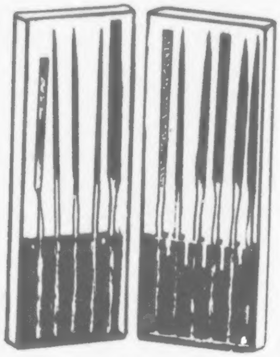


Flat File

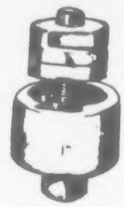
Half-Round File



Square Hole Punch



Precision Files



Round Hole Punch

HAND TOOLS
UNIT III

JOB SHEET #1--CLEAN AND LUBRICATE PLIERS

I. Tools and materials

   A. Pliers

   B. Solvent

   C. Oil

   D. Solvent tray or equivalent

II. Procedure

   A. Lay pliers in tray

   B. Pour solvent into tray until pliers are submersed

      (NOTE: If pliers have cushion grips, immerse only the head.)

   C. Open and close pliers several times while submersed

   D. Let pliers set for three or four minutes in the solvent

   E. Remove from solvent

   F. Open and close rapidly until pliers work freely

      (NOTE: If pliers do not work freely, repeat Steps C through F.)

   G. Wipe residue from plier joint with a cloth or paper towel

   H. Apply two or three drops of oil to joints of the pliers

   I. Work the pliers until the oil has penetrated the joint

   J. Wipe excess oil from pliers

HAND TOOLS
UNIT III

JOB SHEET #2--ADJUST WIRE STRIPPERS

I. Tools and materials

- A. Adjustable wire strippers
- B. Variety of solid insulated conductors
- C. Screwdriver or nut driver to fit adjustment screw

II. Procedure

- A. Loosen adjustment screw (Figure 1)

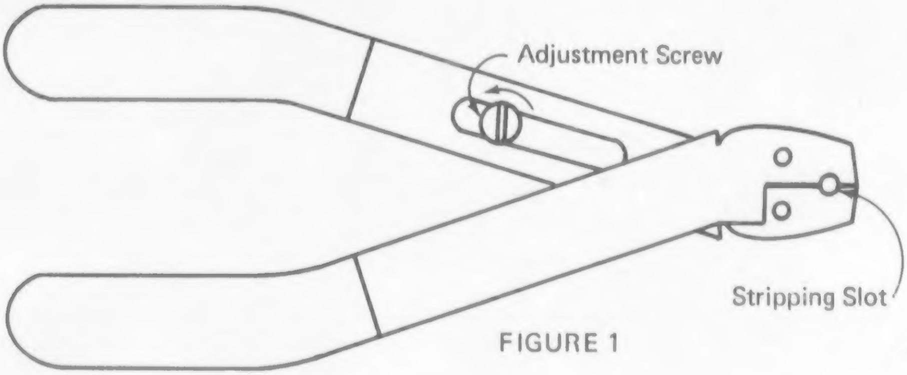


FIGURE 1

- B. Insert conductor into stripping slot
- C. Close jaws until you feel that you have reached the conductor
- D. Open jaws slightly
- E. Slide adjustment screw down to its resting position (Figure 2)

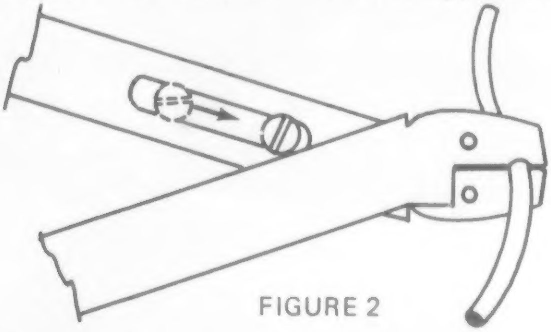


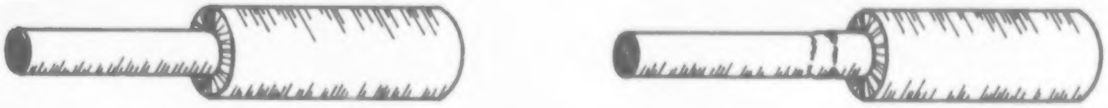
FIGURE 2

JOB SHEET #2

F. Strip off approximately 3/8-inch of insulation

G. Check conductor for ring or nick (Figure 3)

(NOTE: If nick occurs, loosen adjustment screw, readjust, and test again until insulation is removed without conductor damage.)



Correctly Adjusted

Incorrectly Adjusted

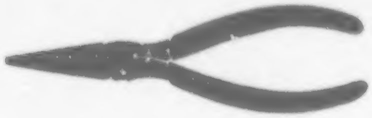
FIGURE 3

HAND TOOLS
UNIT III

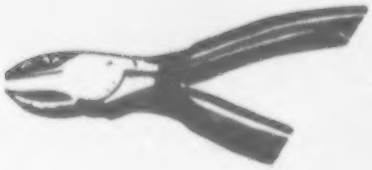
NAME ______________________________

TEST

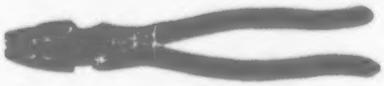
1. Identify the hand tools below.



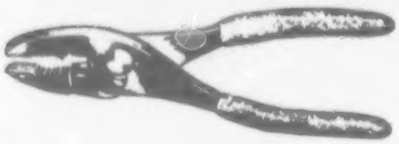
a. ________________________



b. ________________________

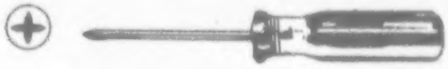


c. ________________________

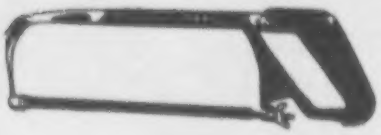


d. ________________________

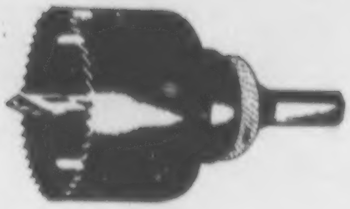
e. ________________________



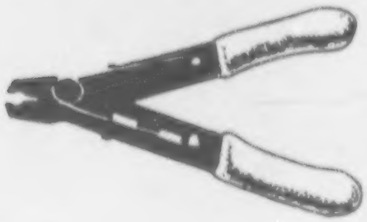
f. ________________________



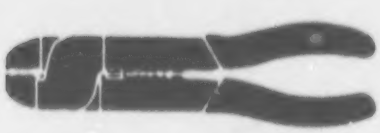
g. ______________________



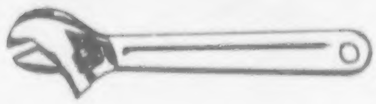
h. ______________________



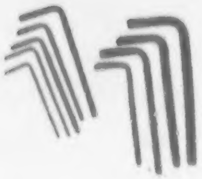
i. ______________________



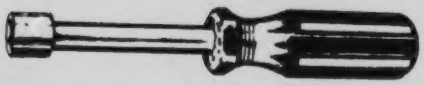
j. ______________________

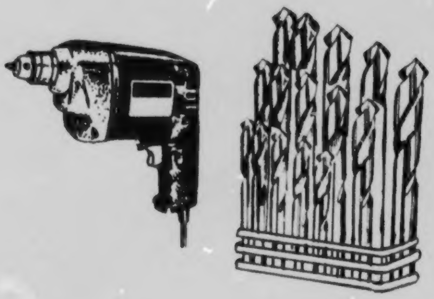


k. ______________________



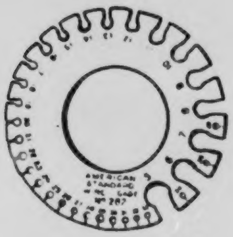
l. ______________________

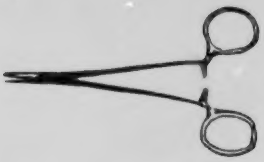




m. ______________________

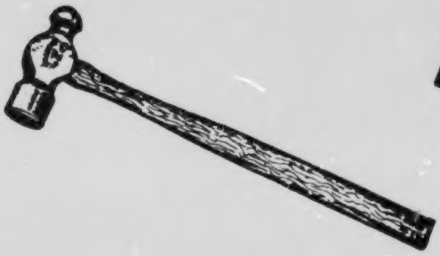
n. ______________________

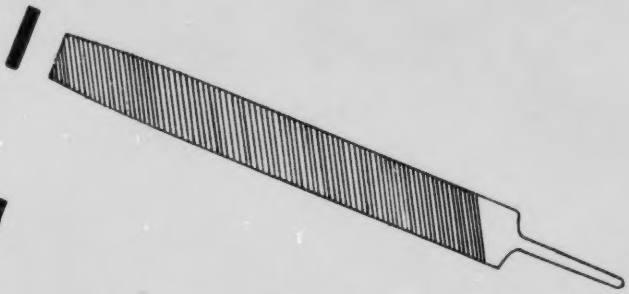




o. ______________________

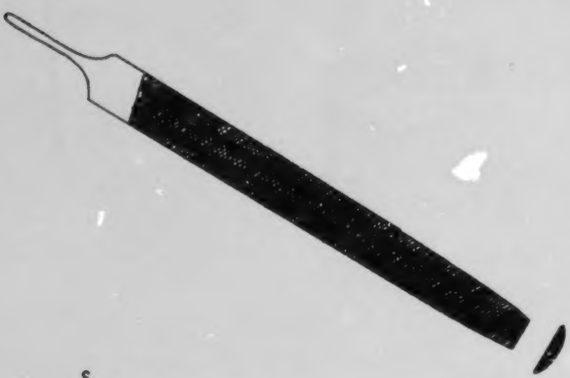
p. ______________________



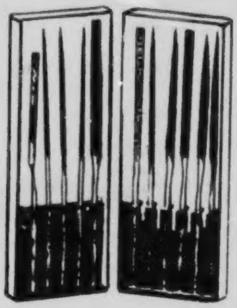


q. ______________________

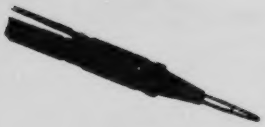
r. ______________________



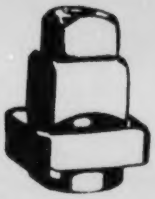
s. ______________________



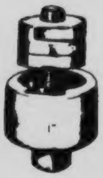
t. ______________________



u. ______________________



v. ______________________



w. ______________________

2. Match the tools on the right to their uses.

_____a. Removing or tightening screws or bolts (flat head or Phillips head)

_____b. 1) Crimping solderless connections
    2) Cutting wire
    3) Stripping insulation from wire
    4) Shearing bolts
    5) Thread gauges
    6) Length gauges for stripping

_____c. 1) Holding components
    2) Heat sink
    3) Shaping and forming small conductors

_____d. 1) Cutting holes up to four inches in diameter
    2) Punching round or square holes in metal

_____e. 1) Holding nuts or bolt heads
    2) Tightening or loosening nuts or bolts

_____f. 1) Cutting chassis metal
    2) Cutting bolts or metal parts

_____g. 1) Cutting heavier conductors and cables
    2) Cutting small screws
    3) Stripping insulation from wires
    4) Forming large conductors

_____h. 1) Cutting wire and component leads
    2) Stripping insulation from wire

_____i. 1) Tightening or loosening socket cap screws
    2) Tightening or loosening set screws

1. Long nose chain pliers
2. Diagonal cutting pliers
3. Lineman's side cutting pliers
4. Combination slip joint pliers
5. Screwdrivers
6. Hacksaw
7. Electrician's six-in-one tool
8. Nut drivers
9. Hex and spline wrenches
10. Hole saws and hole punches

_____j. 1) Loosening small to medium size nuts and bolts

2) Holding and turning

3. List three factors that should be considered when selecting tools.

a. ______________________________

b. ______________________________

c. ______________________________

4. List maintenance procedures for the following tools.

a. Screwdrivers

1) ______________________________

2) ______________________________

b. Pliers

1) ______________________________

2) ______________________________

3) ______________________________

4) ______________________________

c. Adjustable wrenches--______________________________

d. All tools--______________________________

5. Demonstrate the ability to:

a. Clean and lubricate pliers.

b. Adjust wire strippers.

(NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

HAND TOOLS
UNIT III

ANSWERS TO TEST

1. a. Long nose chain pliers
   b. Diagonal cutting pliers
   c. Lineman's side cutting pliers
   d. Combination slip joint pliers
   e. Flat blade (slot-head) screwdriver
   f. Phillips head (cross-point) screwdriver
   g. Hacksaw
   h. Hole saw
   i. Adjustable wire strippers
   j. Electrician's six-in-one tool
   k. Adjustable wrench
   l. Hex and spline wrenches
   m. Nut driver
   n. Drill and drill bits
   o. Wire gauge
   p. Hemostat clamp
   q. Ball peen hammer
   r. Flat file
   s. Half-round file
   t. Precision files
   u. Center punch
   v. Square hole punch
   w. Round hole punch

2.

a.	5	c.	1	e.	8	g.	3	i.	9
b.	7	d.	10	f.	6	h.	2	j.	4

3. Any three of the following:

   a. Tool size should be matched to the work most frequently encountered

   b. Tools should be specifically designed for electronic use whenever possible

      1) Should have insulation on handles of pliers
      2) Should have insulation on handles of screwdrivers

   c. Purchasing quality tools is less expensive in the long run

   d. Know the specifications before purchasing a tool

4. a. Screwdrivers

      1) Regrind worn or damaged flat blade screwdrivers
      2) Discard damaged Phillips screwdrivers

b. Pliers

    1) Keep pliers clean and rust free
    2) Keep cutting edges sharp and smooth
    3) Keep pliers working freely
    4) Repair or replace damaged handle insulation

c. Adjustable wrenches--Keep worm gears clean and lubricated

d. All tools--Identify tools by labeling with an electric vibrator pen or scratch awl

5. Performance skills evaluated to the satisfaction of the instructor

THE NATURE OF MATTER
UNIT I

UNIT OBJECTIVE

After completion of this unit, the student should be able to describe the random drift of electrons and discuss the law of electrical charges. The student should also be able to create and observe the behavior of charges. This knowledge will be evidenced by correctly performing the procedures outlined on the job sheet and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms associated with the nature of matter to the correct definitions.
2. Select the particle not found in the nucleus of the atom.
3. Distinguish between inner and outer orbits.
4. Describe the random drift of electrons.
5. Discuss the law of electrical charges.
6. Demonstrate the ability to create and observe the behavior of charges.

THE NATURE OF MATTER
UNIT I

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information, assignment, and job sheets.

III. Make transparency.

IV. Discuss unit and specific objectives.

V. Discuss information and assignment sheets.

VI. Demonstrate and discuss the procedures outlined in the job sheet.

VII. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

  A. Objective sheet

  B. Information sheet

  C. Transparency Master #1--The Atom and Its Particles

  D. Assignment Sheet #1--Recall Terminology and Concepts

  E. Answers to assignment sheet

  F. Job Sheet #1--Create and Observe the Behavior of Charges

  G. Test

  H. Answers to test

II. Reference--Grob, Bernard. *Basic Electronics.* New York: McGraw-Hill Book Co., 1977.

THE NATURE OF MATTER
UNIT I

INFORMATION SHEET

I. Terms and definitions

A. Matter--Anything that occupies space; can be solid, liquid, or gas

B. Atom--Smallest unit of matter

C. Element--Matter composed entirely of identical atoms

D. Compound--Result when atoms of different elements are joined chemically

E. Molecule--Basic unit of a compound

F. Mixture--Result when substances are together but not joined chemically

G. Electron--Lightest, negatively charged elementary particle, which orbits around the nucleus

H. Proton--Positively charged elementary particle located in the nucleus

I. Neutron--A heavy, uncharged elementary particle which is located in the nucleus

J. Free electrons--Particles in the outermost orbit of an atom which can move freely from one atom to the next

(NOTE: Free electrons are valence electrons.)

K. Ion--An electrically charged atom

L. Charge--An excess or deficiency of electrons

II. Location of atomic particles (Transparency 1)

A. In the nucleus

1. Protons
2. Neutrons

B. Orbiting the nucleus--Electrons

III. Inner and outer orbits

A. Inner orbits--Contains no free electrons

B. Outer orbits

1. Orbit may be partially filled
2. If partially filled, contains free electrons

INFORMATION SHEET

IV. Random drift of electrons--The movement of an electron from the orbit of one atom to the orbit of another atom occurring naturally with no controlling force applied

(NOTE: Even when no controlling or directing force is present, electrons move from the orbit of one atom to the outer orbit of another.)

V. Law of electrical charges

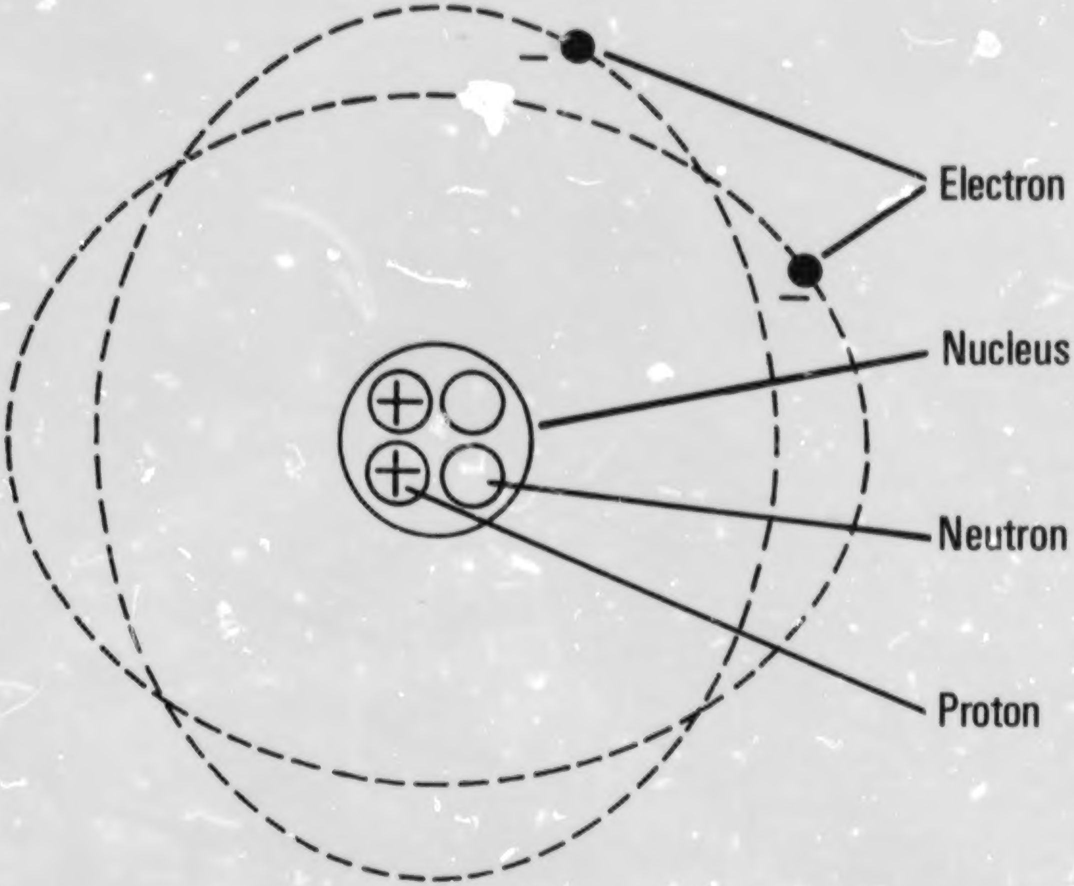
A. Like charges repel

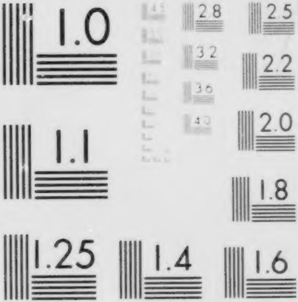
Example: Electrons repel electrons

B. Unlike charges attract

Example: Protons attract electrons

The Atom and Its Particles


Electron
Nucleus
Neutron
Proton


1.0
4.5
2.8
2.5
3.2
2.2
3.6
4.0
2.0
1.1
1.8
1.25
1.4
1.6

MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU OF STANDARDS-1963-A

THE NATURE OF MATTER
UNIT I

ASSIGNMENT SHEET #1--RECALL TERMINOLOGY AND CONCEPTS

1. Fill in the blanks with the proper word.

   a. When substances are together but not joined chemically, the result is called a
   ______________________________________.

   b. The lightest of the three elementary particles is the ____________________.

   c. The ____________________ is the smallest unit of matter.

   d. The elementary atomic particle having no charge is the ____________________.

   e. Anything that occupies space is called ____________________.

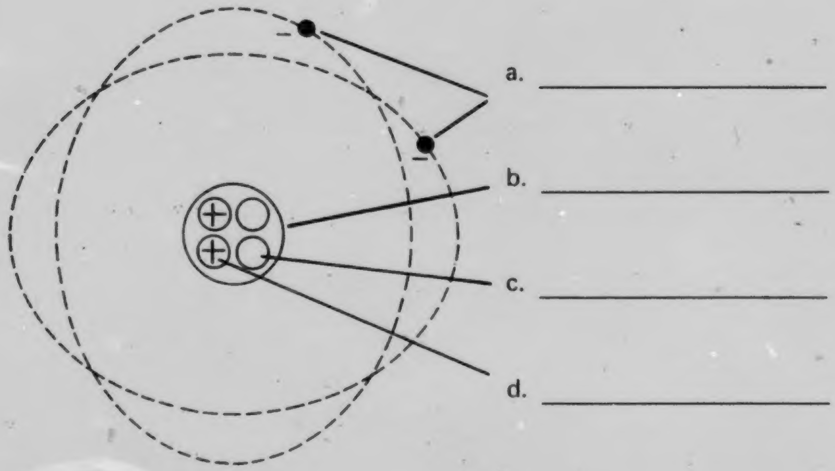
   f. The ____________________ has a positive charge and is in the nucleus of an atom.

   g. ____________________ is matter that is composed of identical atoms.

   h. Atoms of different elements, joined together chemically, are called ____________
   ______________________________________.

   i. The basic unit of a compound is the ____________________.

2. Label the parts of the atom in the diagram below.



3. Free electrons are found in the (inner) (outer) orbits of an atom.

4. Describe "random drift" of electrons in an element.

5. True or false:

   ______a. Two electrons that are close to each other will attract each other.

   ______b. A proton close to an electron will attract it.

   ______c. Two protons close to each other will repel each other.

THE NATURE OF MATTER
UNIT I

ANSWERS TO ASSIGNMENT SHEET #1

1. a. mixture
   b. electron
   c. atom
   d. neutron
   e. matter
   f. proton
   g. An element
   h. compounds
   i. molecule
2. a. electrons
   b. nucleus
   c. neutron
   d. proton
3. outer
4. The random movement of an electron from the outer orbit of one electron to the outer orbit of another.
5. a. false
   b. true
   c. true

THE NATURE OF MATTER
UNIT I

JOB SHEET #1--CREATE AND OBSERVE THE BEHAVIOR OF CHARGES

I. Tools and equipment

   A. Two glass rods

   B. Silk cloth about one foot square

   C. Three feet of twine

II. Procedure

   A. Tie the twine to the center of a glass rod

   B. Suspend the rod by the twine from a convenient support

   C. Rub the suspended rod rapidly with the silk cloth

   D. Bring the cloth close to the end of the suspended rod, being careful not to let the two touch, and observe

   (NOTE: Theory says that when the glass rod is rubbed with silk, millions of electrons are transferred from the glass to the silk. Thus, the silk will have a negative charge and the glass will have a positive charge.)

   E. Rub the suspended rod again with the silk cloth

   F. Rub the other rod with the silk cloth

   G. Bring the second rod tip close to the suspended rod's tip and observe

   (NOTE: When electrons are removed, the protons in the atoms give the glass rods a positive charge. If both rods are positively charged, they will repel each other.)

   H. Touch the ends of the rods to each other

   I. Bring the ends of the two rods close to each other again and observe

   (NOTE: If charged objects touch they tend to neutralize charges. If no charges exist, there is neither attraction nor repulsion.)

BE - 15-B

THE NATURE OF MATTER
UNIT I

NAME ______________________________

TEST

1. Match the terms on the right to the correct definitions.

______a. Result when substances are together but not joined chemically

______b. Smallest unit of matter

______c. Positively charged elementary particle located in the nucleus

______d. Basic unit of a compound

______e. A heavy, uncharged elementary particle which is located in the nucleus

______f. Anything that occupies space; can be solid, liquid, or gas

______g. Lightest, negatively charged elementary particle, which orbits around the nucleus

______h. Matter composed entirely of identical atoms

______i. Result when atoms of different elements are joined chemically

______j. Particles in the outermost orbit of an atom which can move freely from one atom to the next

______k. An excess or deficiency of electrons

______l. An electrically charged atom

1. Matter
2. Atom
3. Element
4. Compound
5. Molecule
6. Mixture
7. Electron
8. Proton
9. Neutron
10. Free electrons
11. Ion
12. Charge

2. Select the particle NOT found in the nucleus of an atom by placing an "X" in the appropriate blank.

______a. Electron

______b. Proton

______c. Neutron

3. Distinguish between inner and outer orbits by placing an "O" next to descriptions of outer orbits.

_____a. If partially filled, contains free electrons

_____b. Orbit may be partially filled

_____c. Contains no free electrons

4. Describe the random drift of electrons.

5. Discuss the law of electrical charges.

6. Demonstrate the ability to create and observe the behavior of charges.

(NOTE: If this activity has not been accomplished prior to the test, ask your instructor when it should be completed.)

THE NATURE OF MATTER
UNIT I

ANSWERS TO TEST

1. a. 6 c. 8 e. 9 g. 7 i. 4 k. 12
   b. 2 d. 5 f. 1 h. 3 j. 10 l. 11

2. a

3. a, b

4. Description should include:

   The movement of an electron from the orbit of one atom to the orbit of another atom occurring naturally with no controlling force applied

5. Discussion should include:

   a. Like charges repel
   b. Unlike charges attract

6. Performance skills evaluated to the satisfaction of the instructor.

SOURCES OF ELECTRICAL ENERGY
UNIT II

UNIT OBJECTIVE

After completion of this unit, the student should be able to match terms to correct definitions and match energy sources to devices that transform them into electrical energy. The student should also be able to use and test batteries, and generate electricity with magnetism, pressure, heat, and light. This knowledge will be evidenced by correctly performing the procedures outlined on the job sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match the terms associated with sources of electrical energy to the correct definitions.
2. Match six major sources of electricity to the proper basic action.
3. Match energy sources to devices that transform them into electrical energy.
4. Demonstrate the ability to:
    a. Use and test batteries.
    b. Generate electricity with magnetism.
    c. Generate electricity with pressure.
    d. Generate electricity with heat.
    e. Generate electricity with light.

SOURCES OF ELECTRICAL ENERGY
UNIT II

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information and job sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information sheet.

VI. Demonstrate and discuss the procedures outlined in the job sheets.

VII. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:
  A. Objective sheet
  B. Information sheet
  C. Transparency masters
    1. TM 1--Chemical Action Produces Electricity
    2. TM 2--Magnetism Produces Electricity
    3. TM 3--Light Produces Electricity
    4. TM 4--Heat Produces Electricity
    5. TM 5--Pressure Produces Electricity
    6. TM 6--Friction Produces Electricity
  D. Job sheets
    1. Job Sheet #1--Use and Test Batteries
    2. Job Sheet #2--Generate Electricity With Magnetism
    3. Job Sheet #3--Generate Electricity With Pressure
    4. Job Sheet #4--Generate Electricity With Heat
    5. Job Sheet #5--Generate Electricity With Light

E. Test

F. Answers to test

II. References:

A. Grob, Bernard. *Basic Electronics*. New York: McGraw-Hill, 1977.

B. Marcus, Abraham. *Basic Electronics*. Englewood Cliffs, NJ: Prentice-Hall.

SOURCES OF ELECTRICAL ENERGY
UNIT II

INFORMATION SHEET

I. Terms and definitions

- A. Battery cell--Device that transforms chemical energy into electrical energy
- B. Electrolyte--Conducting liquid in battery in which ions move
- C. Energy--Capacity to do work
- D. Generator--Device that transforms mechanical energy into electrical energy
- E. Alternator--Generator that produces alternating current
- F. Photoelectric effect--A method of transforming light energy into electrical energy
- G. Thermocouple--Device that transforms heat energy into electrical energy
- H. Piezoelectric effect--A way of transforming pressure into electrical energy
- I. Magnet--Material with property of attracting iron and producing a magnetic field external to itself
- J. Static electricity--Stationary charges of electricity
- K. Hydrometer--An instrument that determines specific gravity of a fluid
- L. Specific gravity--The density of a liquid compared to water

II. Major sources of electricity and basic actions

- A. Chemical source--Opposite charges produced on two different kinds of cell plates
- B. Magnetic source--Moving parts with magnet which generates electricity
- C. Light source--Electrons emitted when light strikes surface; photoelectric effect
- D. Heat source--Two dissimilar metals joined together when heated produces electricity
- E. Pressure source--Physical distortion of small crystal
- F. Friction source--Rubbing two objects together

INFORMATION SHEET

III. Energy sources and devices that transform them into electrical energy

A. Chemical source (Transparency 1)

1. Car battery
2. Dry cell

(NOTE: A chemical process within a battery causes electron flow from the anode through the electrolyte to the cathode.)

B. Magnetic source (Transparency 2)

1. Car alternator
2. Water-powered generator

(NOTE: Electricity is generated when there is relative motion between a conductor and a magnetic field.)

C. Light source (Transparency 3)

1. Light meter
2. Solar cell

(NOTE: Photoelectric materials create electron flow when exposed to light.)

D. Heat source (Transparency 4)--Thermocouple

(NOTE: A thermocouple is two metals made up of different materials which produce an electric voltage when exposed to a source of heat.)

E. Pressure source (Transparency 5)

1. Phonograph pickup
2. Microphone

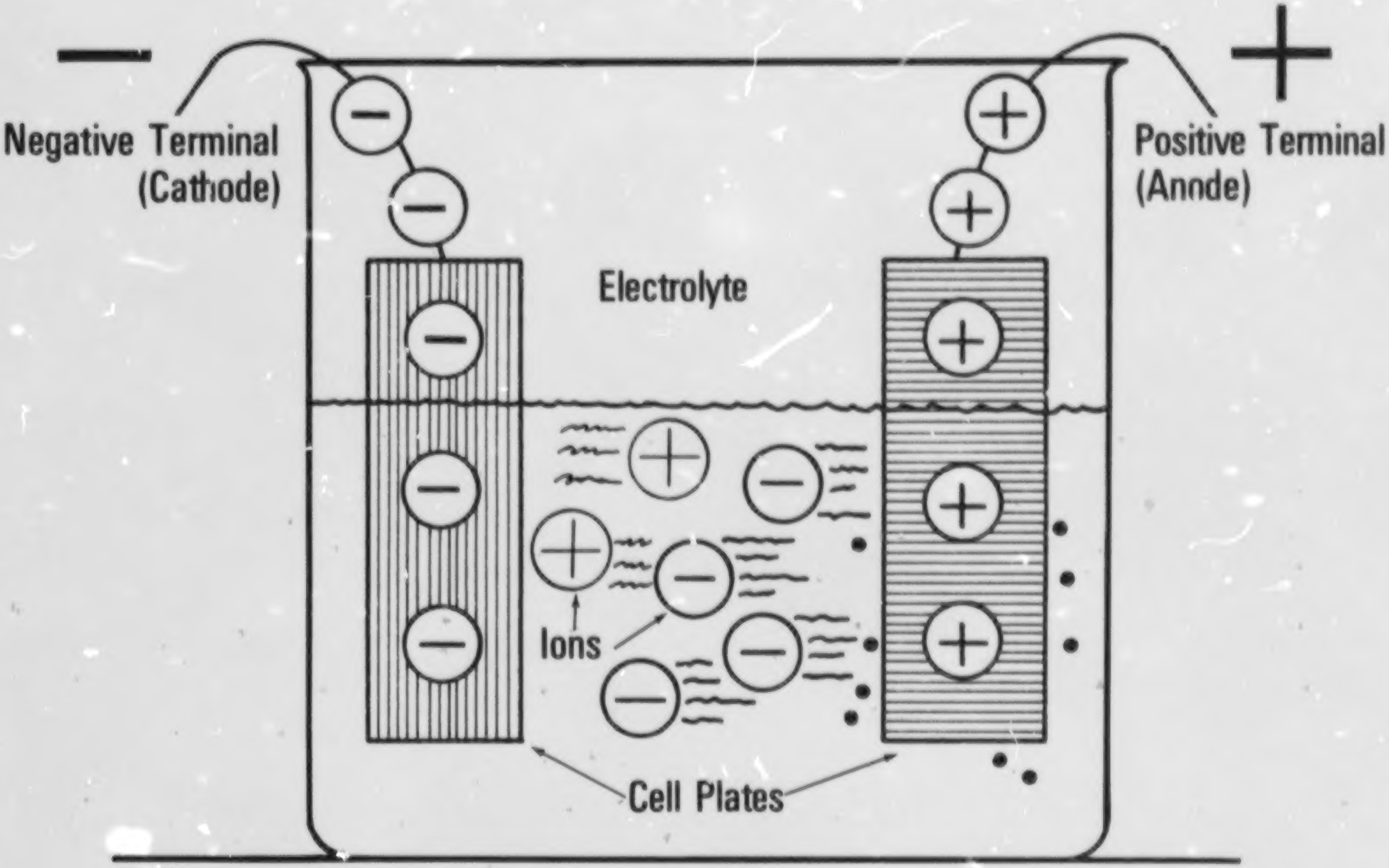
(NOTE: Pressure applied to certain types of crystals produce electricity. This is called a piezoelectric effect.)

F. Friction source (Transparency 6)

1. Nylon carpet in winter
2. Van de Graaff generator

(NOTE: Friction can cause a static charge build up which produces electricity.)

Chemical Action Produces Electricity



—

Negative Terminal
(Cathode)

+

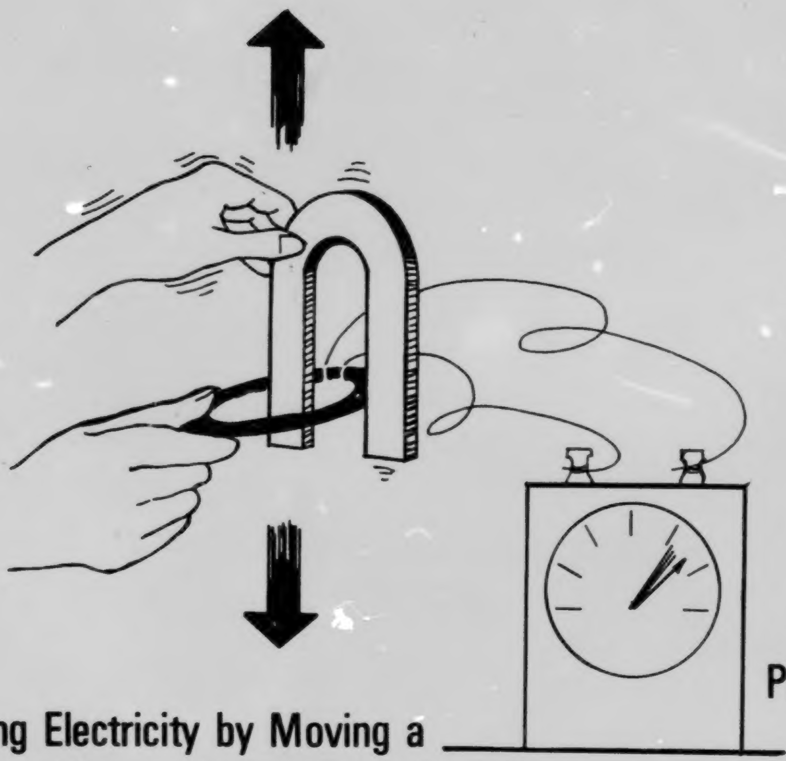
Positive Terminal
(Anode)

Electrolyte

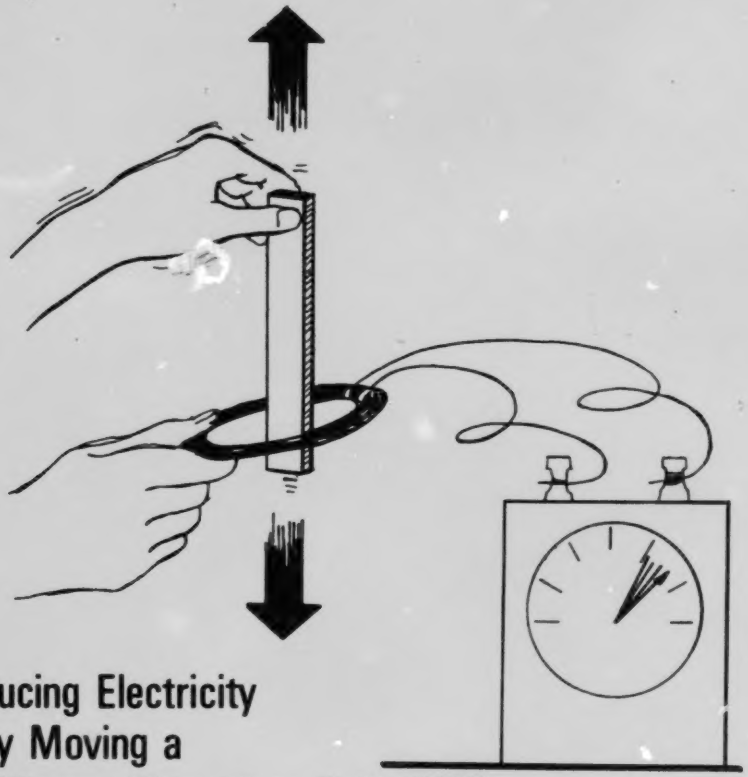
Ions

Cell Plates

Magnetism Produces Electricity

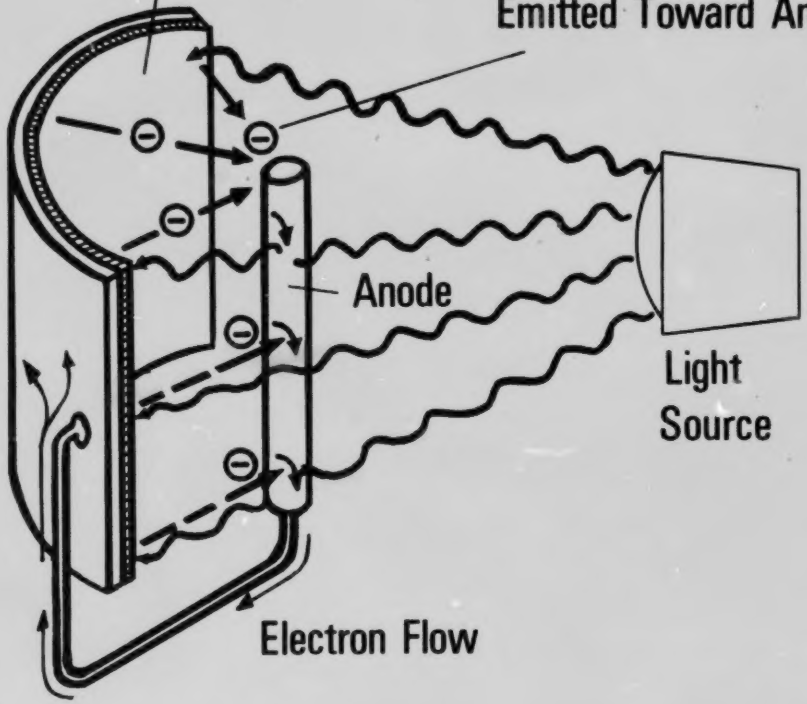


Producing Electricity by Moving a Horseshoe Magnet Through a Coil of Wire



Producing Electricity by Moving a Bar Magnet Through a Coil of Wire

Light Produces Electricity



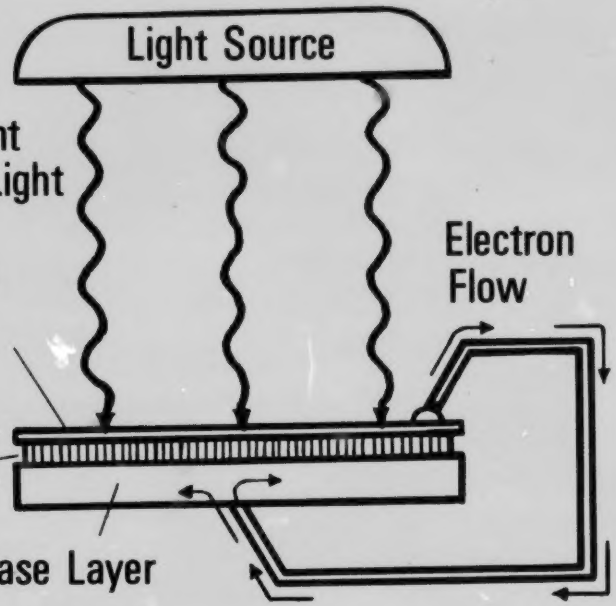
Photosensitive Silver Oxide Surface

Electrons Emitted Toward Anode

Anode

Light Source

Electron Flow



Light Source

Semitransparent Layer Passes Light and Collects Photo electrons

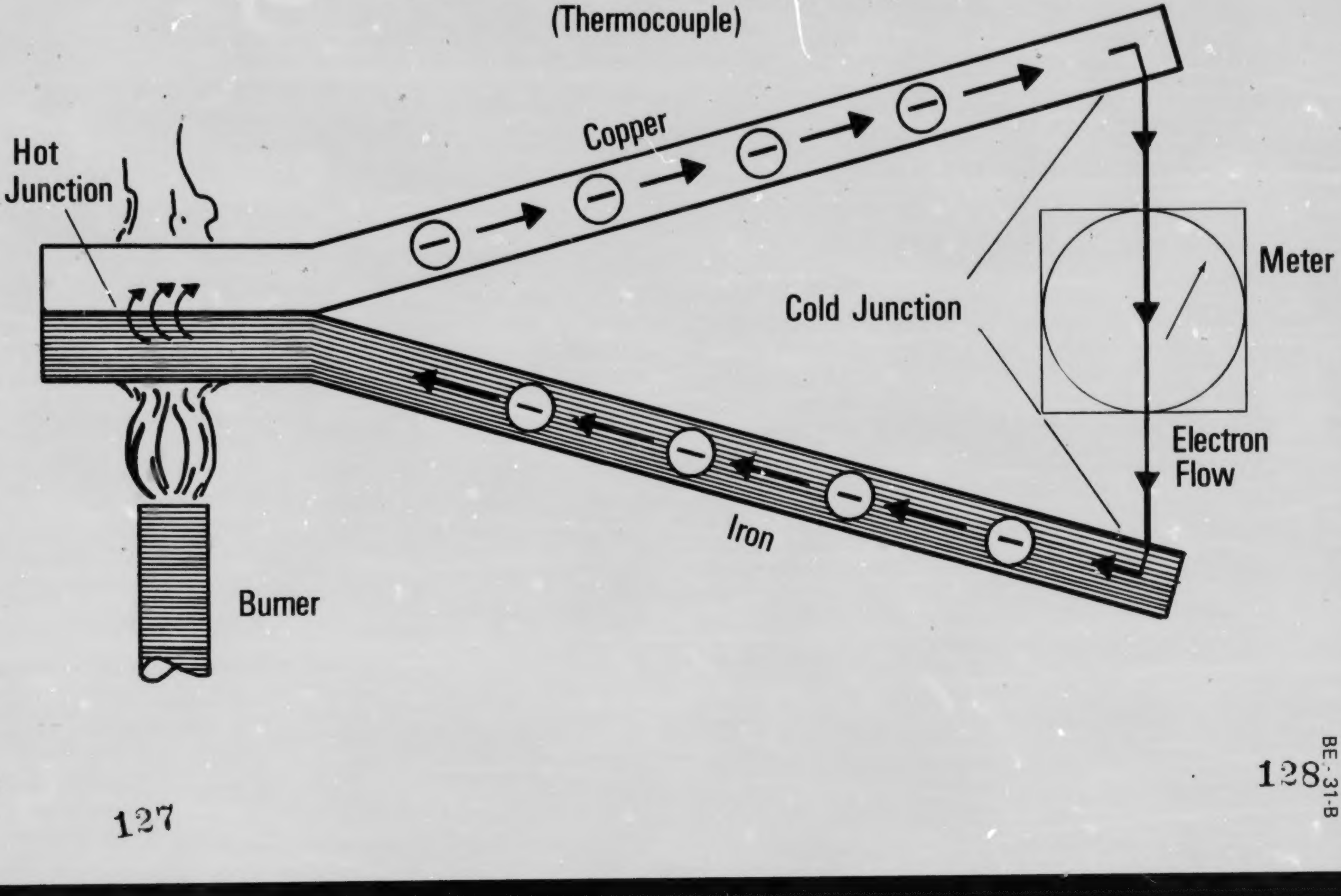
Electron Flow

Photosensitive Copper Oxide

Pure Copper Base Layer

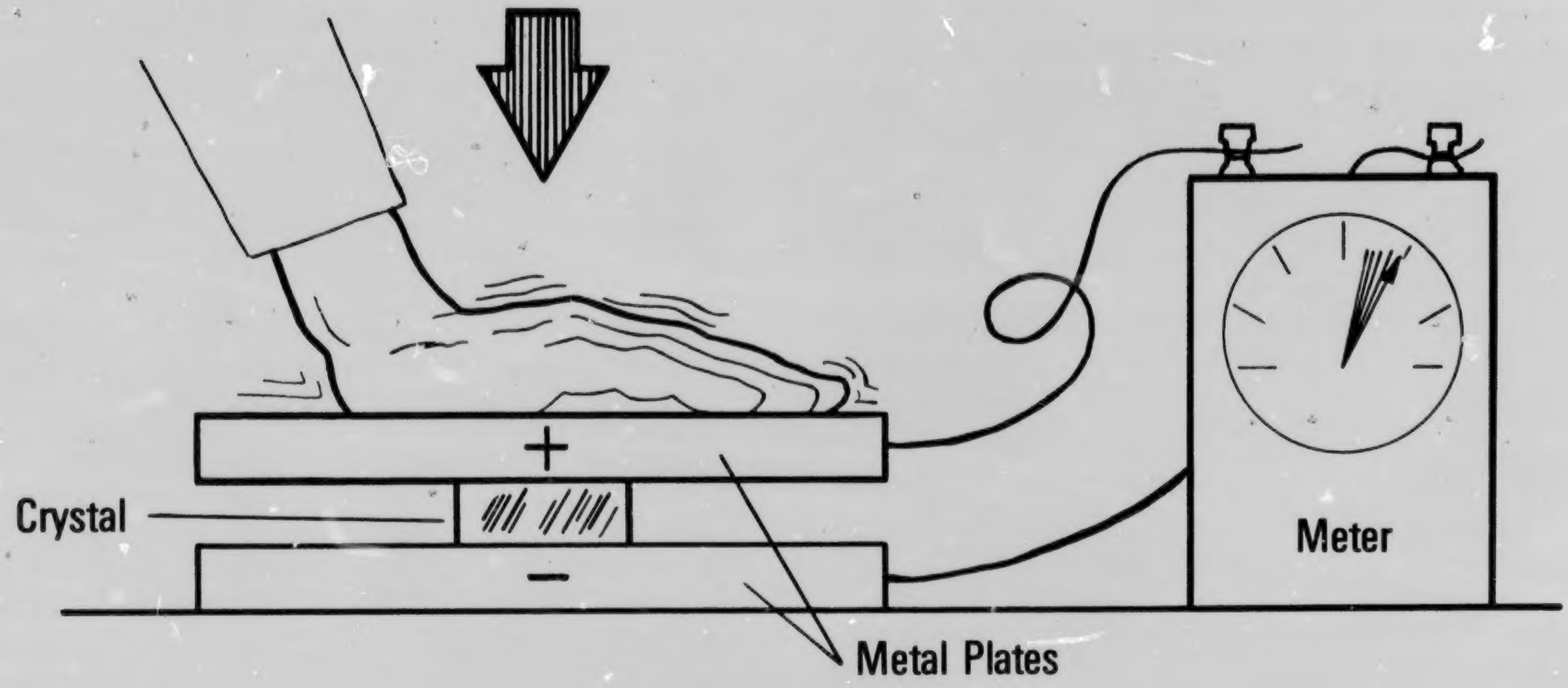
Heat Produces Electricity

(Thermocouple)

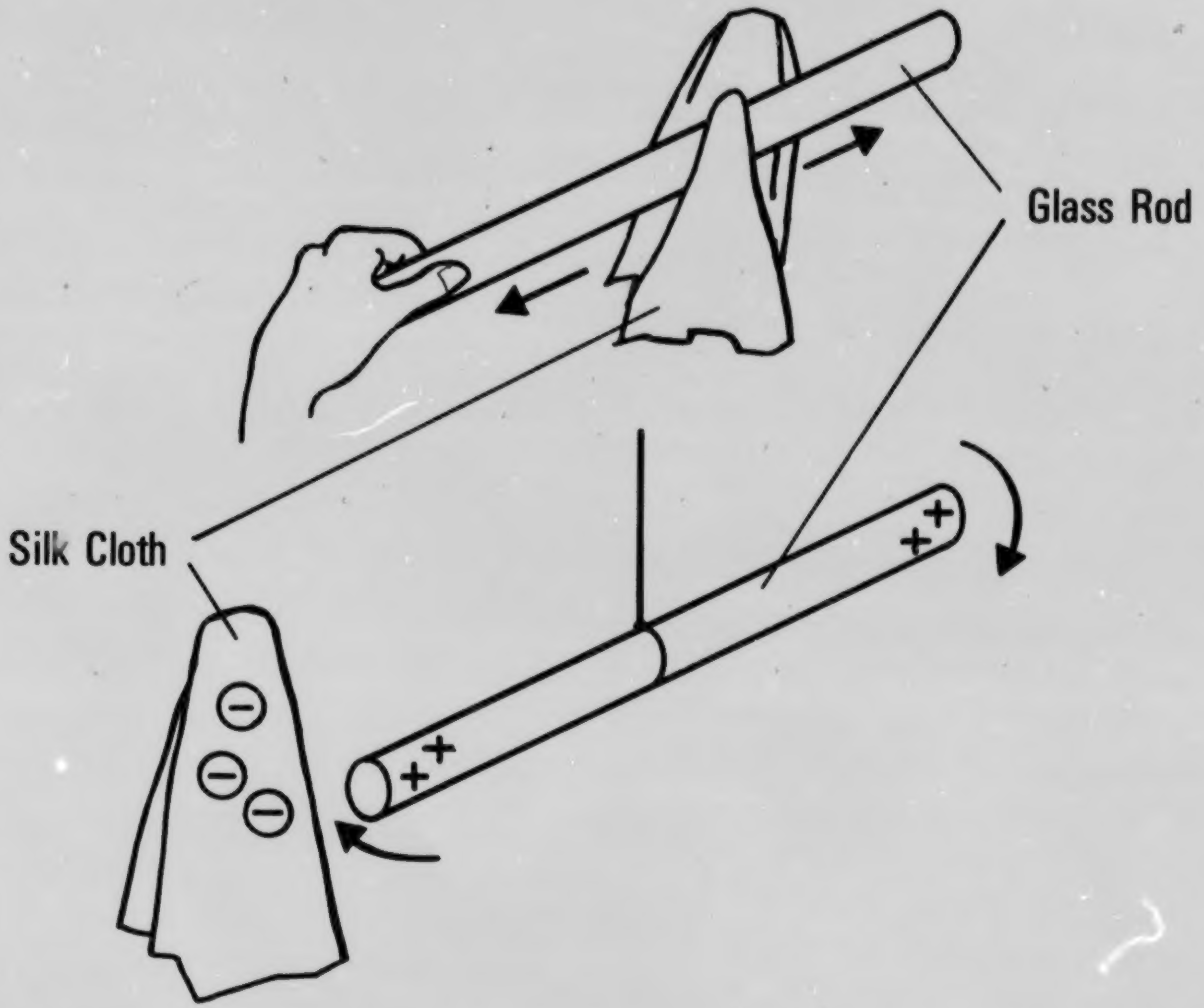

Hot Junction
Copper
Meter
Cold Junction
Electron Flow
Iron
Burner

Pressure Produces Electricity

(Piezoelectric Effect)


+
Crystal
−
Meter
Metal Plates

Friction Produces Electricity


Glass Rod
Silk Cloth
+
+
+
+
−
−
−

SOURCES OF ELECTRICAL ENERGY
UNIT II

JOB SHEET #1--USE AND TEST BATTERIES

I. Tools and materials

   A. Multimeter or voltmeter

   B. 1 1/2 volt battery

   C. Automobile battery (with accessible cells)

   D. Assorted dry-cell batteries (such as camera batteries or flashlight batteries including carbon-zinc, alkaline, nickel-cadmium, and silver oxide)

   E. 1 1/2 volt lamp

   F. Hydrometer

II. Procedure

   A. Examine the assortment of dry cell batteries and note the physical sizes and the voltage markings, if any, on the batteries

   B. Discuss whether or not the various dry cell batteries are rechargeable

   C. Connect the voltmeter across the 1 1/2 volt battery; then read and record the voltage

   D. Connect the 1 1/2 volt lamp across the 1 1/2 volt battery, then with the lamp connected, read and record the voltage

   E. Disconnect the voltmeter and lamp from the battery

   F. Remove a cell cover from the automobile battery

   G. Carefully withdraw sufficient electrolyte from the battery into the hydrometer to cause the float to be suspended

   (CAUTION: The electrolyte is an acid. Do not spill on your skin or your clothes.)

   H. Read and record the hydrometer float level

   I. Discuss the meaning of the float level with your instructor

SOURCES OF ELECTRICAL ENERGY
UNIT II

JOB SHEET #2--GENERATE ELECTRICITY WITH MAGNETISM

I. Tools and materials

  A. Magnet (preferably a bar magnet)

  B. Compass

  (NOTE: A galvanometer or voltmeter can be used for the compass.)

  C. 36 inches, approximately, of hook-up wire

II. Procedure

  A. Wrap about four turns of wire around your compass, then loosely wrap the rest of the wire around the bar magnet

  B. Wind the wire so that the ends will be close enough to be connected

  (NOTE: The wire forms a continous loop. See Figure 1.)

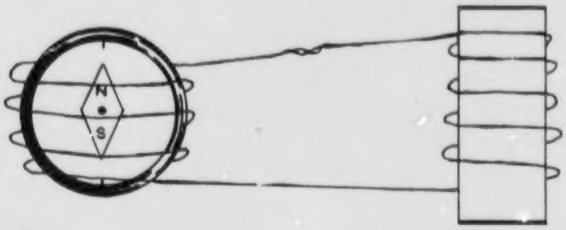


FIGURE 1

  C. Move the magnet out of the "coil" of wire and observe the movement of the compass needle

  D. Move the magnet back into the coil and observe the movement of the compass needle

  E. Hold the magnet still and move the wire coil while observing the compass

SOURCES OF ELECTRICAL ENERGY
UNIT II

JOB SHEET #3--GENERATE ELECTRICITY WITH PRESSURE

I. Tools and materials

   A. Phonograph crystal in holder with needle

   B. Voltmeter or galvanometer

II. Procedure

   A. Connect the voltmeter or galvanometer to the phonograph crystal connections

   (NOTE: Do this on the back of the crystal holder away from the needle end.)

   B. Move the needle slightly with your finger and observe the meter

   (NOTE: When playing a record the needle is in the record groove which causes movement relating to the recording.)

SOURCES OF ELECTRICAL ENERGY
UNIT II

JOB SHEET #4--GENERATE ELECTRICITY WITH HEAT

I. Tools and materials

  A. 18" of copper wire

  B. 18" of iron wire

  C. Galvanometer or voltmeter

  D. Candle and matches

II. Procedure

  A. Strip 3" of insulation from each end of both the iron and copper wires

  B. Connect each wire to the galvanometer

  C. Twist tightly together the other end of the iron and copper wires

  D. Light the candle and hold the twisted iron-copper "thermocouple" over the flame, and watch the meter needle carefully

  (CAUTION: Do not overheat the junction of the two wires. Remove from the flame from time to time and let cool.)

  E. Observe the meter when the wires are heated and when they are cooled

SOURCES OF ELECTRICAL ENERGY
UNIT II

JOB SHEET #5--GENERATE ELECTRICITY WITH LIGHT

I. Tools and materials

  A. Photocell or solar cell

  (NOTE: A photographer's light meter can be substituted.)

  B. Galvanometer or voltmeter and connecting wires

  C. Flashlight or other light source

  D. Piece of black cloth

II. Procedure

  A. Locate the output connections on the photocell

  B. Connect the photocell to the galvanometer

  C. Cover the photocell with the black cloth and observe the meter

  D. Uncover the photocell and observe the meter (room lighting)

  E. Shine the flashlight directly into the photocell and observe the meter

SOURCES OF ELECTRICAL ENERGY
UNIT II

NAME ______________________________

TEST

1. Match the terms on the right to the correct definitions.

_____ a. Generator that produces alternating current

_____ b. A way of transforming pressure into electrical energy

_____ c. Conducting liquid in battery in which ions move

_____ d. Stationary charges of electricity

_____ e. Device that transforms chemical energy into electrical energy

_____ f. A method of transforming light energy into electrical energy

_____ g. Capacity to do work

_____ h. Device that transforms heat energy into electrical energy

_____ i. Device that transforms mechanical energy into electrical energy

_____ j. Material with property of attracting iron and producing a magnetic field external to itself

_____ k. An instrument that determines specific gravity of a fluid

_____ l. The density of a liquid compared to water

1. Specific gravity
2. Electrolyte
3. Energy
4. Generator
5. Alternator
6. Photoelectric effect
7. Thermocouple
8. Piezoelectric effect
9. Magnet
10. Static electricity
11. Battery cell
12. Hydrometer

2. Match the major source of electricity on the right with the proper basic action.

_____ a. Electrons emitted when light strikes surface; photoelectric effect

_____ b. Physical distortion of small crystal

_____ c. Opposite charges produced on two different kinds of cell plates

_____ d. Moving parts with magnet which generates electricity

1. Chemical source
2. Magnetic source
3. Light source
4. Heat source
5. Pressure source
6. Friction source

______e. Two dissimilar metals joined together when heated produces electricity

______f. Rubbing two objects together

3. Match the sources of energy on the right to the devices that transform them into electrical energy.

______a. Light meter

______b. Thermocouple

______c. Van de Graaff generator

______d. Dry cell

______e. Phonograph pick-up

______f. Car alternator

1. Magnetic source
2. Pressure source
3. Friction source
4. Chemical source
5. Heat source
6. Light source

4. Demonstrate the ability to:

   a. Use and test batteries.

   b. Generate electricity with magnetism.

   c. Generate electricity with pressure.

   d. Generate electricity with heat.

   e. Generate electricity with light.

(NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

SOURCES OF ELECTRICAL ENERGY
UNIT II

ANSWERS TO TEST

1.	a.	5	e.	11	i.	4
	b.	8	f.	6	j.	9
	c.	2	g.	3	k.	12
	d.	10	h.	7	l.	1
2.	a.	3	d.	2		
	b.	5	e.	4		
	c.	1	f.	6		
3.	a.	6	d.	4		
	b.	5	e.	2		
	c.	3	f.	1		

4. Performance skills evaluated to the satisfaction of the instructor

CIRCUIT FUNDAMENTALS
UNIT I

UNIT OBJECTIVE

After completion of this unit, the student should be able to select true statements about the relationship of charges according to Coulomb's law and true statements concerning the relationship of voltage, current, and resistance according to Ohm's law. The student should also be able to identify basic elements in a circuit schematic and construct a basic circuit from a schematic. This knowledge will be evidenced by correctly performing the procedures outlined in the job sheet and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms associated with circuit fundamentals with their correct definitions.
2. State Coulomb's law.
3. Select true statements about the relationship of charges according to Coulomb's law.
4. Select true statements concerning the relationship of voltage, current, and resistance according to Ohm's law.
5. Complete a chart of circuit characteristics.
6. Match basic schematic symbols with the circuit elements they identify.
7. Identify basic elements in a circuit schematic.
8. Complete a schematic showing current flow.
9. Select true statements about open and closed circuits.
10. Demonstrate the ability to construct a basic circuit from a schematic.

CIRCUIT FUNDAMENTALS
UNIT I

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information and job sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information sheet.

VI. Demonstrate and discuss the procedures outlined in the job sheet.

VII. Demonstrate schematic representations and actual components.

VIII. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:
  A. Objective sheet
  B. Information sheet
  C. Transparency masters
    1. TM 1--Basic Circuit Elements--Power Sources
    2. TM 2--Basic Circuit Elements--Resistance and Load
    3. TM 3--Basic Circuit Elements--Switches
    4. TM 4--Schematic Showing Circuit Elements
    5. TM 5--Schematic Showing Current Flow
    6. TM 6--Schematics Showing Circuit On-Off Condition
  F. Job Sheet #1--Construct a Basic Circuit from a Schematic
  G. Test
  H. Answers to test

II. References:

A. Grob, Bernard. *Basic Electronics.* New York: McGraw-Hill, 1977.

B. Jakobowitz, Henry. *Electronics Made Simple.* Garden City, NY: Doubleday & Co., Inc.

C. Marcus, Abraham, and Samuel E. Gendler. *Basic Electronics.* Englewood Cliffs, NJ: Prentice-Hall, 1971.

CIRCUIT FUNDAMENTALS
UNIT I

INFORMATION SHEET

I. Terms and definitions

  A. Charge--A stored quantity of electrical energy

  B. Attraction--The force that causes unlike charges to move toward each other

  C. Repulsion--The force that causes like charges to move away from each other

  D. Electrical current--The movement of electrons

  E. Simple circuit--A few electrical components, connected by a conductor, through which electrical energy can flow

  Example: A battery, switch, and lamp connected by wire

  F. Schematic--A diagram of an electrical circuit which uses symbols for electrical components

  G. Voltage--Electrical pressure or force supplied by a source of electricity, such as a battery

  H. Current--The flow of electrons through an electrical circuit

  I. Resistance--The opposition to electrical current flow including the wire and all components in a circuit which absorb energy

  J. Load--The total resistance in a circuit; this determines how much electrical energy the power source must supply

  K. Circuit conductors--Any wires which connect circuit elements

  L. Circuit wiring--Wires used in an electrical circuit

II. Coulomb's law--The force of attraction or repulsion varies directly with the amount of the charges and inversely with the square of the distance between them

(NOTE: This is also called the law of electrical charges.)

III. Relationship of charges in Coulomb's law

  A. Like charges repel

    1. A positive charge repels another positive charge

    2. A negative charge repels another negative charge

INFORMATION SHEET

B. Unlike charges attract

  1. A negative charge attracts a positive charge

  2. A positive charge attracts a negative charge

IV. Relationship of voltage, current, and resistance according to Ohm's law (E=IR)

  A. If voltage is held constant

    1. Increasing resistance decreases current

    2. Decreasing resistance increases current

  B. If resistance is held constant

    1. Increasing voltage increases current

    2. Decreasing voltage decreases current

  C. If current is held constant

    1. Increasing resistance increases voltage

    2. Decreasing resistance decreases voltage

V. Circuit characteristics

Circuit characteristics	Symbol	Source	Unit of Measure
Charge	Q or q	Electrons	Coulomb
Voltage*	E or e V or v	Potential difference between two unlike charges	Volt
Current	I or i	Number of electrons per second moving through the circuit	Ampere
Resistance (or load)	R or r	The opposition to the flow of current using energy	Ohm

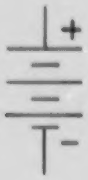
(* E and e are sometimes used for generated voltages and in formulas. V and v are preferred.)

INFORMATION SHEET

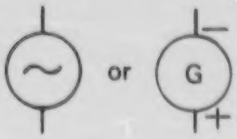
VI. Basic circuit elements and symbols

A. Power sources (Transparency 1)

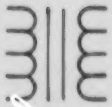
1. Battery



2. Generator

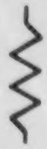


3. Transformer

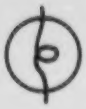


B. Resistance and load (Transparency 2)

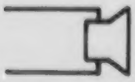
1. Resistor



2. Lamp



3. Loudspeaker

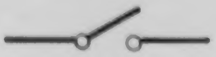


(NOTE: All wires used in the electrical circuit provide a certain amount of resistance to current. All the devices connected to the circuit to produce light or heat offer resistance to current flow. This is called load.)

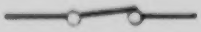
INFORMATION SHEET

C. Circuit switches (Transparency 3)

1. Switch open

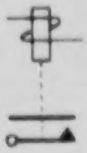


2. Switch closed

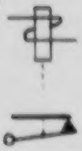


(NOTE: In the switch open position, current cannot flow through the circuit. In the switch closed position, current can flow through the circuit. These are hand operated switches.)

3. Relay open



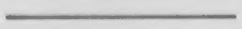
4. Relay closed



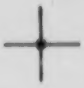
(NOTE: The relay open and relay closed are electrically operated switches.)

D. Circuit conductors (wires)

1. Conductor

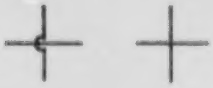


2. Conductors connected



INFORMATION SHEET

3. Conductors not connected



VII. Basic elements in a circuit schematic (Transparency 4)

A. Power source

(NOTE: This could be a battery, generator, transformer or power supply.)

B. Conductors

(NOTE: This is usually wiring.)

C. Loads

(NOTE: Resistors, lamps, and loudspeakers are loads.)

D. Switches

(NOTE: This includes manual switches and relays.)

VIII. Current flow schematic (Transparency 5)

A. Electrons are negatively charged particles

B. Electrons move toward a positive charge

C. In a closed circuit, electrons flow from the negative side of the battery, through the closed circuit, and return to the positive side of the battery

D. Direction of current flow is noted with directional arrows

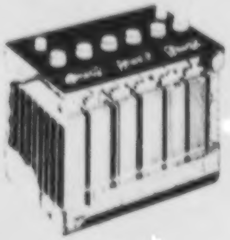
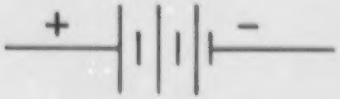
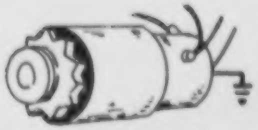
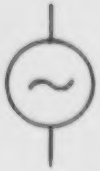
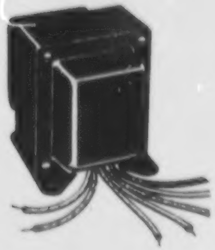
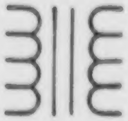
IX. Open and closed circuits (Transparency 6)

A. Current cannot flow in an open circuit

B. Current can flow in a closed circuit

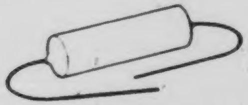
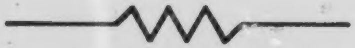
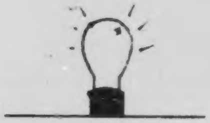
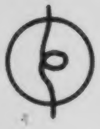
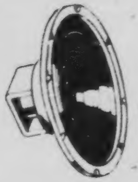
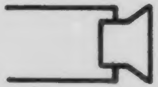
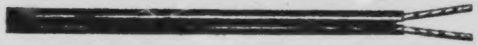
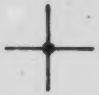
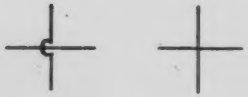
Basic Circuit Elements

Power Sources

Element	Picture	Schematic Symbol
Battery		
Generator		
Transformer		

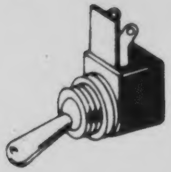
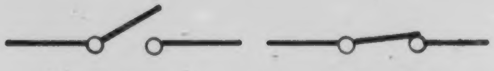
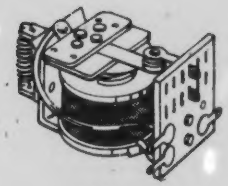
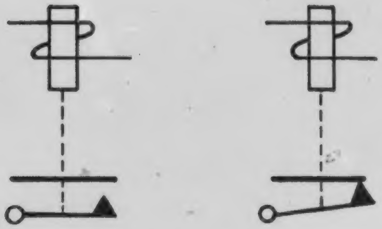
Basic Circuit Elements

Resistance and Load

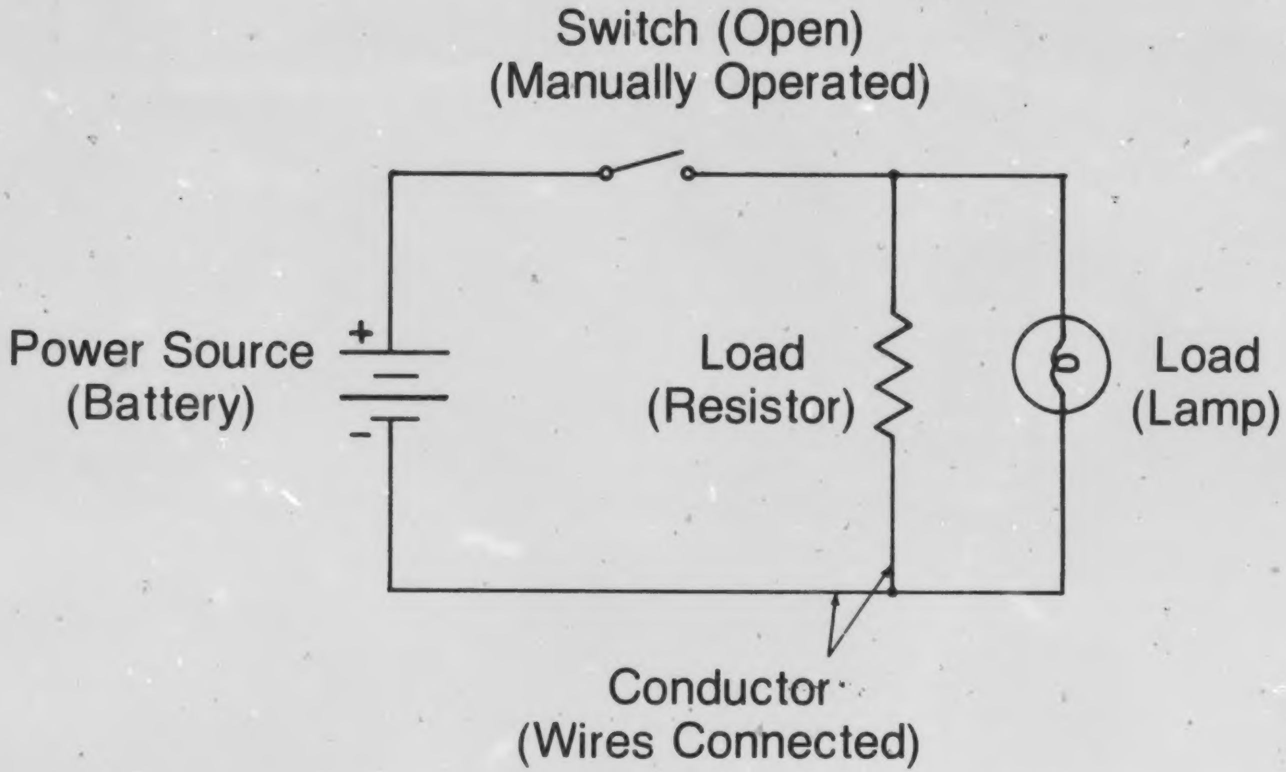
Element	Picture	Schematic Symbol
Resistor		
Lamp		
Loudspeaker		
Electrical Wires		 Connected  Not Connected

Basic Circuit Elements

Switches

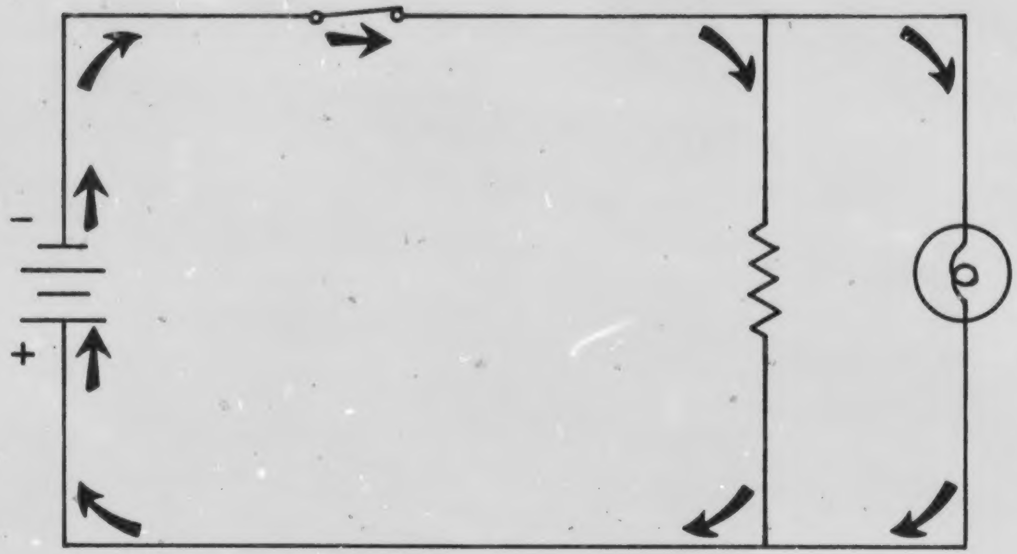
Element	Picture	Schematic Symbol
Hand-Operated Switch		 Open Closed
Relay		 Open Closed

Schematic Showing Circuit Elements


Switch (Open)
(Manually Operated)
Power Source
(Battery)
+
-
Load
(Resistor)
Load
(Lamp)
Conductor
(Wires Connected)

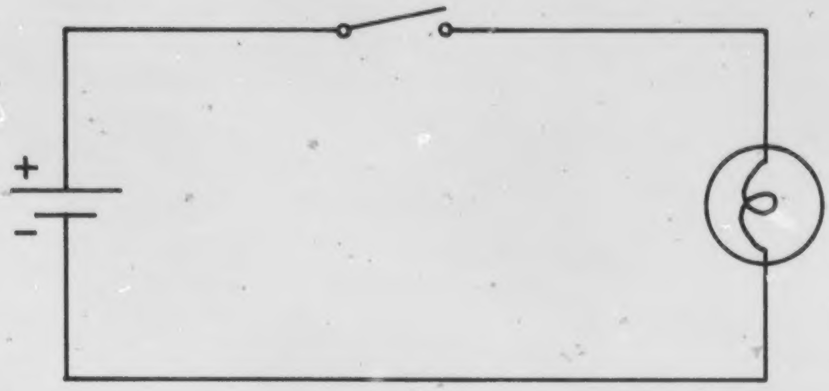
Schematic Showing Current Flow

Switch Closed

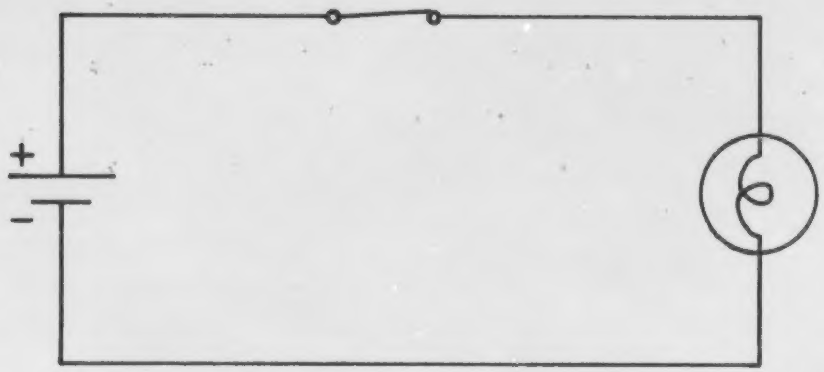

Negative
–
Positive
+
The Lamp (Load) Is Energized (Glows)

Electricity flows from the Negative (-) side of the battery, through the closed circuit, back to the Positive (+) side of the battery.

Schematics Showing Circuit On-Off Condition



Open Circuit (Current Cannot Flow)



Closed Circuit (Current Will Flow)

CIRCUIT FUNDAMENTALS
UNIT I

JOB SHEET #1--CONSTRUCT A BASIC CIRCUIT FROM A SCHEMATIC

I. Tools and materials

   A. Power supply or 1-1/2 volt battery

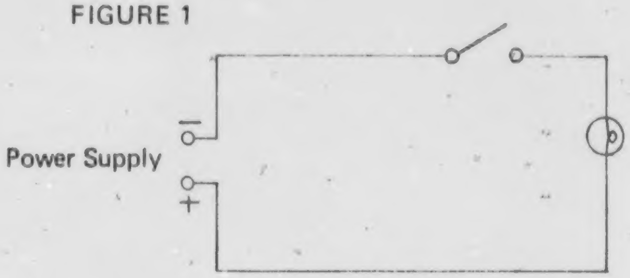
   B. Bulb #47, or see your teacher for proper lamp type

   C. Switch, SPST

II. Procedure

   A. Wire together the simple circuit in Figure 1

FIGURE 1



   B. Have the instructor check for proper wiring and adjust the power supply voltage.

   C. Turn the switch on and off and observe that the bulb lights, then goes off.

   (NOTE: The following questions may be used for discussion:

   1. How is the negative terminal of the battery indicated on the schematic in Figure 1?
   2. What might happen if the power supply were connected with opposite polarity?
   3. What is the purpose of the switch in the circuit?
   4. What are the different ways of connecting the wires to the three electrical components?)

   D. Return tools and materials to proper storage area

BE - 25-C

CIRCUIT FUNDAMENTALS
UNIT I

NAME ______________________

TEST

1. Match the terms on the right with the correct definitions.

______a. The flow of electrons through an electrical circuit

______b. The force that causes unlike charges to move toward each other

______c. A few electrical components, connected by a conductor, through which electrical energy can flow

______d. A stored quantity of electrical energy

______e. The force that causes like charges to move away from each other

______f. The opposition to electrical current flow including the wire and all components in a circuit which absorb energy

______g. The total resistance of a circuit; this determines how much electrical energy the power source must supply

______h. A diagram of an electrical circuit which uses symbols for electrical components

______i. Electrical pressure or force supplied by a source of electricity, such as a battery

______j. The movement of electrons

______k. Any wires which connect circuit elements

______l. Wires used in an electrical circuit

1. Charge
2. Attraction
3. Repulsion
4. Electrical current
5. Simple circuit
6. Schematic
7. Voltage
8. Current
9. Resistance
10. Load
11. Circuit wiring
12. Circuit conductors

2. State Coulomb's law.

3. Select true statements about the relationship of charges according to Coulomb's law by placing an "X" in the appropriate blanks.

_____a. Like charges repel

_____b. Unlike charges repel

_____c. A positive charge attracts another positive charge

_____d. A negative charge repels another negative charge

_____e. A positive charge attracts a negative charge

_____f. A negative charge repels a positive charge

4. Select true statements concerning the relationship of voltage, current, and resistance according to Ohm's law by placing an "X" in the appropriate blanks.

_____a. If voltage is held constant, increasing resistance decreases current

_____b. If voltage is held constant, decreasing resistance increases current

_____c. If resistance is held constant, increasing voltage decreases current

_____d. If resistance is held constant, decreasing voltage decreases current

_____e. If current is held constant, increasing resistance increases voltage

_____f. If current is held constant, decreasing resistance increases voltage

5. Complete the following chart of circuit characteristics.

Circuit Characteristics	Symbol	Source	Unit of Measurement
Charge	Q or q	a. __________	Coulomb
Voltage	b. ________	Potential difference between two unlike charges	c. ______________
Current	I or i	d. __________	e. ______________
Resistance (or load)	f. ________	The opposition to the flow of current using energy	Ohm

6. Match the schematic symbols on the right with the circuit elements they identify.

______a. Resistor

______b. Conductors not connected

______c. Lamp

______d. Generator

______e. Transformer

______f. Relay open

______g. Relay closed

______h. Switch closed

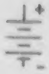
______i. Loudspeaker

______j. Switch open

______k. Conductor connected

______l. Battery

______m. Conductor

1.


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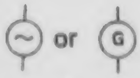

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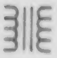

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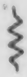

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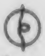

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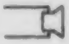

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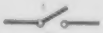

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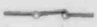

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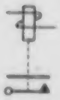

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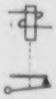

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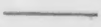

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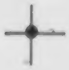

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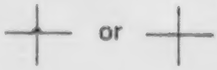


7. Identify basic elements in the circuit schematic.

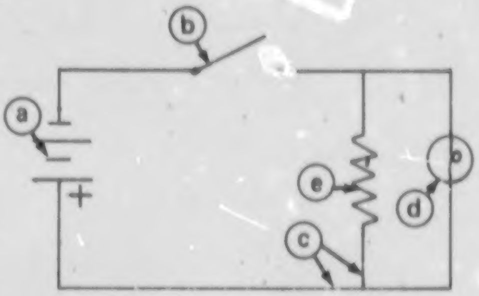
a. ______________________________

b. ______________________________

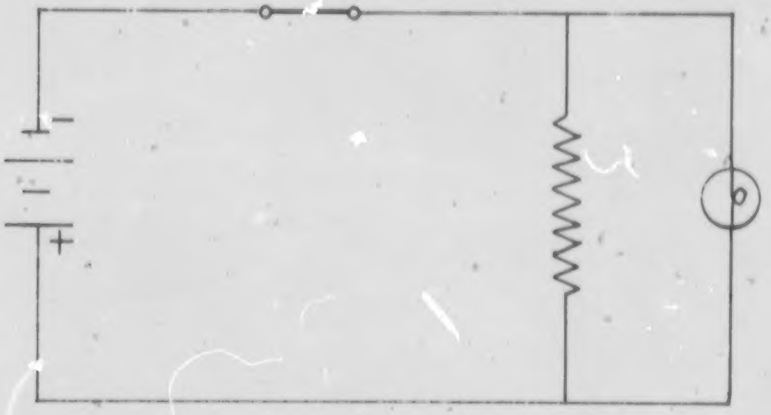
c. ______________________________

d. ______________________________

e. ______________________________



8. Complete a schematic showing current flow by adding the correct directional arrows to the schematic below.



9. Select true statements about open and closed circuits by placing an "X" in the appropriate blanks.

_____a. Current can flow in an open circuit

_____b. Current cannot flow in a closed circuit

_____c. Current can flow in a closed circuit

_____d. Current cannot flow in an open circuit

10. Demonstrate the ability to construct a basic circuit from a schematic.

(NOTE: If this activity has not been accomplished prior to the test, ask your instructor when it should be completed.)

CIRCUIT FUNDAMENTALS
UNIT I

ANSWERS TO TEST

1. a. 8 c. 5 e. 3 g. 10 i. 7 k. 12
   b. 2 d. 1 f. 9 h. 6 j. 4 l. 11

2. The force of attraction or repulsion varies directly with the amount of the charges and inversely with the square of the distance between them

3. a, d, e

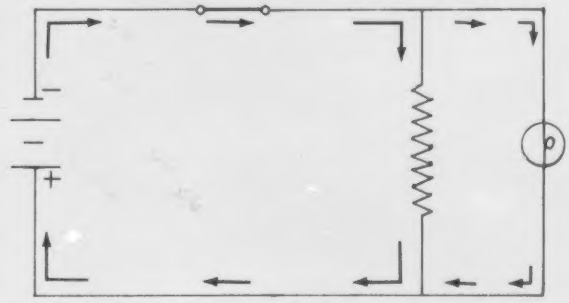
4. a, b, d, e

5. a. Electrons
   b. E or e; V or v
   c. Volt
   d. Number of electrons per second moving through the circuit
   e. Ampere
   f. R or r

6. a. 4 d. 2 f. 9 h. 8 j. 7 l. 1
   b. 13 e. 3 g. 10 i. 6 k. 12 m. 11
   c. 5

7. a. Power source
   b. Switch
   c. Conductor
   d. Load (lamp)
   e. Load (resistor)

8. Arrows should move from negative terminal up, to the right, and back to the positive terminal



9. c, d

10. Performance skill evaluated to the satisfaction of the instructor

SOLDERING AND CIRCUIT FABRICATION
UNIT II

UNIT OBJECTIVE

After completion of this unit, the student should be able to select true statements about cleaning before and after soldering, wire stripping and tinning, and soldering procedures, and match types of poor solder connections with their causes. The student should also be able to strip and tin wire, solder wires to various terminals, splice wires together by soldering and crimping, and connect ends of printed wiring. This knowledge will be evidenced by correctly performing the procedures outlined on the job sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms associated with soldering and circuit fabrication with their definitions.
2. Match soldering tools and materials with their uses.
3. Select true statements about cleaning before and after soldering.
4. Select true statements about wire stripping and tinning.
5. Select true statements about soldering procedures.
6. Select characteristics of a good solder connection.
7. Match types of poor solder connections with their causes.
8. Name types of soldered connections for degrees of mechanical security required prior to soldering.
9. Demonstrate the ability to:
    a. Strip and tin wire for soldered connections.
    b. Solder wires to turret terminals, then de-solder wires.
    c. Solder wire to a terminal strip.
    d. Repair a printed circuit board by replacing resistors and correcting open or broken lands.
    e. Splice wires together by means of soldering and crimping (flat cable).
    f. Connect ends of flexible printed wiring (flat cable).

SOLDERING AND CIRCUIT FABRICATION
UNIT II

SUGGESTED ACTIVITIES

I. Provide students with objective sheet.

II. Provide students with information and job sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information sheet.

VI. Demonstrate and discuss the procedures outlined in the job sheets.

VII. Take tour of local electronic circuit fabrication shop to observe assembly-line circuit fabrication techniques.

VIII. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

   A. Objective sheet

   B. Information sheet

   C. Transparency masters

      1. TM 1--Typical Soldering Tools
      2. TM 2--Typical Soldering Tools (Continued)
      3. TM 3--Wire Stripping
      4. TM 4--Proper Soldering Technique
      5. TM 5--A Good Solder Joint
      6. TM 6--Poor Solder Connections
      7. TM 7--Appearance and Cause of Poor Solder Joints
      8. TM 8--Soldered Connections--No Mechanical Security Prior to Soldering
      9. TM 9--Soldered Connections--With Mechanical Security Prior to Soldering

D. Job sheets

1. Job Sheet #1--Strip and Tin Wires for Soldered Connections
2. Job Sheet #2--Solder Wires to Turret Terminals, Then De-Solder Wires
3. Job Sheet #3--Solder Wires to a Terminal Strip
4. Job Sheet #4--Repair a Printed Circuit Board by Replacing Resistors and Correcting Open or Broken Lands
5. Job Sheet #5--Splice Wires Together by Means of Soldering and Crimping (Flat Cable)
6. Job Sheet #6--Connect Ends of Flexible Printed Wiring (Flat Cable)

E. Test

F. Answers to test

II. References:

A. *AWS Committee on Brazing and Soldering, Soldering Manual.* 2nd ed., revised. Miami, FL: American Welding Society, Inc., 1978.

B. Manko, Howard H. *Solders and Soldering.* New York: McGraw-Hill Book Co., 1964.

C. Herrick, C. *Electronic Assembly Techniques.* Milwaukie, OR: Hickock Teaching Systems, Inc., 1970.

D. Schlabach, T.D. and Rider, D.K. *Printed and Integrated Circuitry.* New York: McGraw-Hill Book Co., Inc., 1963.

SOLDERING AND CIRCUIT FABRICATION
UNIT II

INFORMATION SHEET

I. Terms and definitions

   A. Oxides--Films and impurities which form on the surface of metals when exposed to air or water and which, if not cleaned off, will prevent a good bond between the surfaces and solder

   B. Rosin--A material obtained from pine trees which is used during soldering to help ensure a good bond between the solder and the metal surfaces

   C. Wetting--The ability of molten solder to flow over and fuse completely with the metal surfaces to which it is applied

   (NOTE: Dirt, grease, and oxides prevent good wetting during soldering.)

   D. Stripping--Removing insulation from electrical conductors

   E. Tinning--The application of a small amount of solder to surfaces to be soldered to help ensure good wetting during soldering

   F. Flux--A liquid or solid which when heated cleans and protects surfaces to be soldered

   G. Crimping--Applying mechanical pressure to compress a sleeve-type or cup-type electrical terminal to ensure a good electrical connection between the sleeve and the conducting wires it contains

   H. Land--Printed wiring attached to the surface of a printed circuit board

II. Soldering tools and materials and their uses (Transparencies 1 and 2)

   A. Soldering iron, 100 watt--For soldering large electrical connections

   B. Soldering pencil, 10 to 35 watts--For soldering small electrical connections

   C. Soldering gun, 100 watts--For soldering large electrical connections where better heat control is required

   D. Resistance soldering unit--For soldering many connections in close spaces

   E. Heat sink--For drawing heat from soldered connection to prevent damage to components

INFORMATION SHEET

F. Component lead cleaner--For removing oxides and other films from component leads

G. Typewriter eraser--For removing oxides and other films from terminals to be soldered

H. Isopropyl alcohol--For removing oil, grease, and flux from conductors and terminals both before and after soldering

I. Mechanical wire strippers--For cutting and pulling insulation from ends of conductors

J. Thermal wire strippers--For removing wire insulation by heating and melting the material; prevents removing wire strands, but cannot be used on insulation that will not melt, such as glass braid or asbestos

K. Solder--For making electrical connections; most common type is 60/40 rosin-core solder containing 60% tin and 40% lead, with a center core of rosin flux to allow simultaneous application of both solder and flux

L. Long nose and needle nose pliers--For making mechanical connection prior to soldering; may also be used as heat sink during soldering

M. Diagonal cutting pliers--For cutting conductors

N. Soldering iron stand--For supporting a hot soldering iron when not in use

O. Soldering vise-For clamping and holding a printed circuit board or other component during soldering or other repair operations

P. Flux--For ensuring a good electrical connection by cleaning and wetting all surfaces during soldering; not required if the solder contains a rosin core

Q. Adjustable power source--For controlling soldering iron tip temperature

(NOTE: Variac is a commonly used adjustable power source.)

R. Crimping tool--For making a strong mechanical connection to certain sleeve-type terminals

S. Spaghetti-sleeve insulation--For preventing electrical connections from becoming shorted to adjacent connections

T. Solder sucker--For removing melted solder from a terminal to be resoldered

(NOTE: There are many different brands available including Soldawick and Soldavac, etc.)

INFORMATION SHEET

U. Heat shrink insulation--Sleeve-type insulation which, when heated, shrinks to form a snug fit over a soldered connection

III. Cleaning before and after soldering

(CAUTION: Use safety goggles or glasses when soldering.)

A. Oil, grease, and dirt--Wipe with isopropyl alcohol and clean cloth

B. Old solder--Heat with soldering iron, and wick away, or suck up by means of a solder sucker

C. Oxides

1. Component leads--Use component lead cleaner
2. Terminals--Use typewriter eraser

D. Rosin flux--Wipe or brush with isopropyl alcohol or other flux cleaner

(CAUTION: Use alcohol only in well-ventilated spaces and do not permit open flames in the vicinity.)

IV. Stripping and tinning (Transparency 3)

A. Make clean cut at wire end by cutting off small length with diagonal cutting pliers

B. Lay wire in proper size slot of wire strippers and strip approximately one inch of insulation from wire end

(CAUTION: If too small a slot in the wire strippers is used for stripping, the stripper will cut off some of the wire strands. This could result in an electrical connection of higher resistance than desirable.)

C. Care must be taken not to remove wire strands when stripping

D. If wire strands have been separated, gently re-twist wire in same direction as original twist

E. After stripping, clean the wire strands with isopropyl alcohol and paper towel

F. Place heat sink on wire strands immediately adjacent to wire insulation before tinning

G. Tin soldering iron tip as follows:

1. Plug in unit and allow it to heat up
2. Wipe tip with paper towel or wet sponge

INFORMATION SHEET

3. As soon as tip will melt solder, coat tip with solder; wipe off excess

H. If rosin-core solder will not be used, wipe small amount of liquid or paste rosin flux on bare strands of stripped wire

I. Set hot soldering iron in holder or vise

J. Melt small bead of solder on iron tip and slowly draw bare wire through solder bead from heat sink toward wire end; apply additional solder as needed

(CAUTION: After the wire has been tinned, the outline of the wire strands should still be visible. If they are not, too much solder has been applied. Reheat wire and wipe off excess solder. If some strands are still loose, too little solder has been applied. Reheat wire and apply additional solder.)

K. Remove heat sink from tinned wire

L. After solder has cooled, clean the tinned wire with isopropyl alcohol and paper towel

V. Soldering procedure (Transparency 4)

A. Clean all surfaces to be soldered

B. Strip and tin wires to be soldered

C. If electrical connection is to be insulated, slide approximately one-inch length of spaghetti insulation onto the tinned wire

D. If possible, mechanically connect tinned wire to terminal or lug by means of long nose or needle nose pliers; make sure distance between terminal and wire insulation is no more than 1/32 to 1/8 inch, depending on wire gauge

E. If mechanical connection is not possible, make sure component to be soldered is held stationary in vise or clamp to prevent movement during soldering

F. Select proper soldering iron for the job, depending on:

1. Size of connection
2. Heat sensitivity of components
3. Proximity of other connections and wires

G. Heat and tin the soldering iron

H. Attach heat sink as close as possible to connection without interfering with soldering operation

INFORMATION SHEET

- I. If rosin-core solder is not to be used, brush small amount of rosin flux on terminal
- J. While making sure that no part of the connection moves, apply hot iron tip to terminal and wire, and apply solder to wire, component, or terminal lead; remove iron tip and solder as soon as solder has flowed freely over, around, and through the connection
- K. After solder has cooled, clean connection with isopropyl alcohol
- L. If connection is to be insulated, slide spaghetti sleeving over connection
- M. If applicable, remove component from vise or clamp

VI. Characteristics of a good solder connection (Transparency 5)

- A. Silvery, shiny appearance to solder surface
- B. Good wetting of solder to surfaces
- C. Solder completely covers connection, but contour of connection is still visible
- D. Insulation
  1. No burnt areas
  2. No damaged insulation
  3. Gap between insulation and connection is approximately the diameter of the wire insulation
- E. No spilled solder
- F. No pits or holes in solder surface

VII. Types of poor solder connections and causes (Transparencies 6 and 7)

- A. Cold solder joint--Insufficient heat
- B. Disturbed joint--Connection moved before solder solidified
- C. Excessive solder--Too much solder applied
- D. Insufficient solder--Too little solder applied
- E. Dewetted solder joint--Insufficient cleaning or insufficient use of flux
- F. Burnt insulation--Excessive heat or carelessness with iron

INFORMATION SHEET

G. Insulation damage--Excessive heat applied, excessive iron application time, or lack of heat sink

H. Rosin solder joint--Excessive rosin or insufficient heat

I. Solder short--Excessive solder or carelessness

VIII. Types of soldered connections

A. No mechanical connection prior to soldering (Transparency 8)

1. Butt connections (no mechanical security)

a. Wire-to-wire

b. Flat-to-flat

(NOTE: Butt connections are used rarely in electrical circuits.)

2. Lap connections (no mechanical security)

a. Wire-to-wire

b. Wire-to-flat

c. Flat-to-flat

d. Wire-to-post

e. Wire-to-cup or sleeve

f. Wire-to-hole

B. Partial mechanical connection prior to soldering (Transparency 9)

1. Wire-to-hook

2. Wire-to-flat lug

3. Wire-to-turret or post

C. Full mechanical connection prior to soldering (Transparency 9)

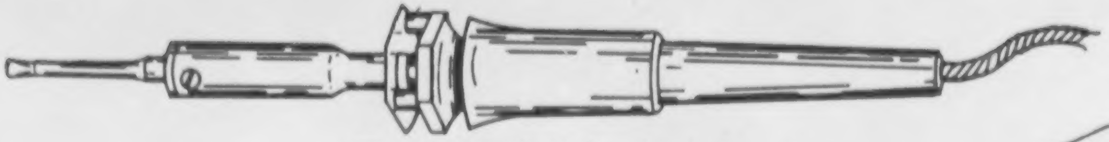
1. Wire spliced to wire

2. Wire to flat lug

3. Wire to turret or post

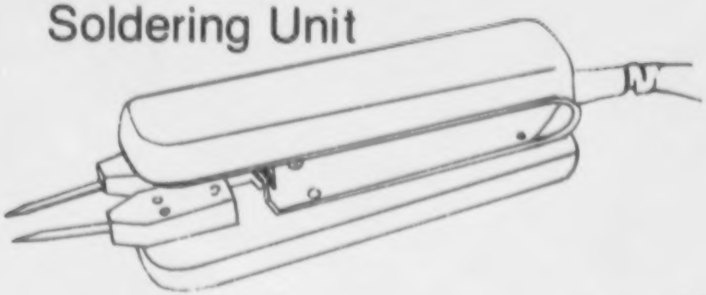
4. Wire to crimp sleeve

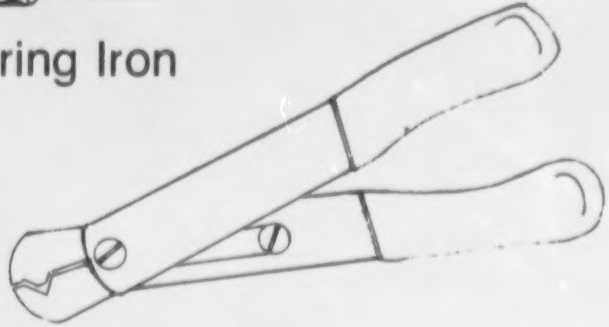
Typical Soldering Tools



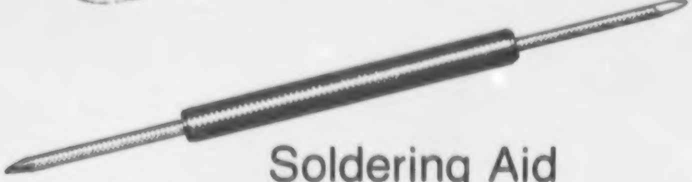
Pencil Soldering Iron

Resistance
Soldering Unit

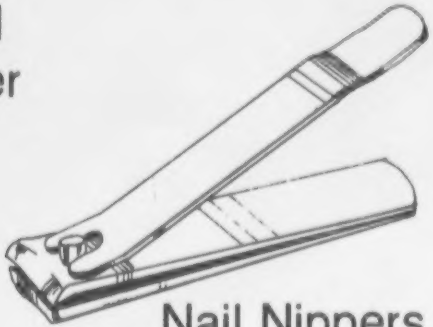




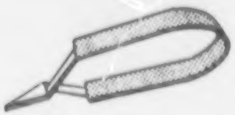
Mechanical
Wire Stripper



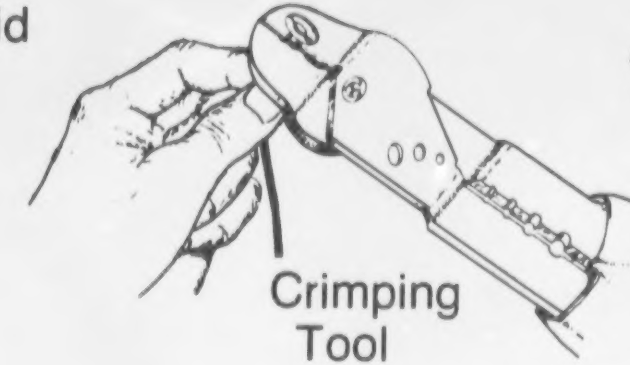
Soldering Aid



Nail Nippers



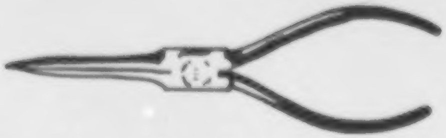
Heat Sink



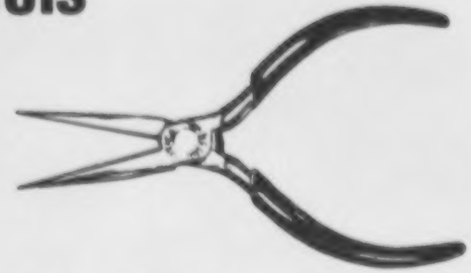
Crimping
Tool

Typical Soldering Tools

(Continued)

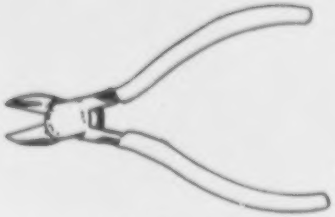


Long Needle Nose Pliers

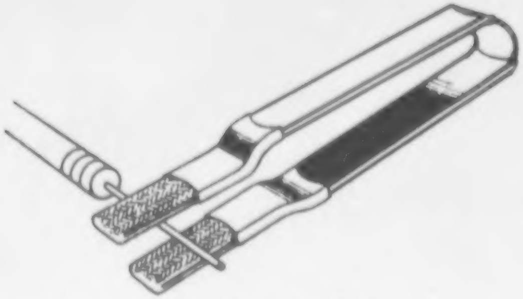


Long Chain Nose Pliers

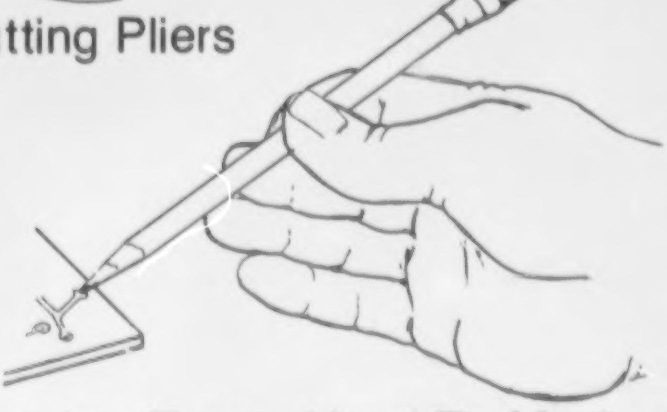
Electrician's Standard Size
Cutting Pliers



Diagonal Cutting Pliers



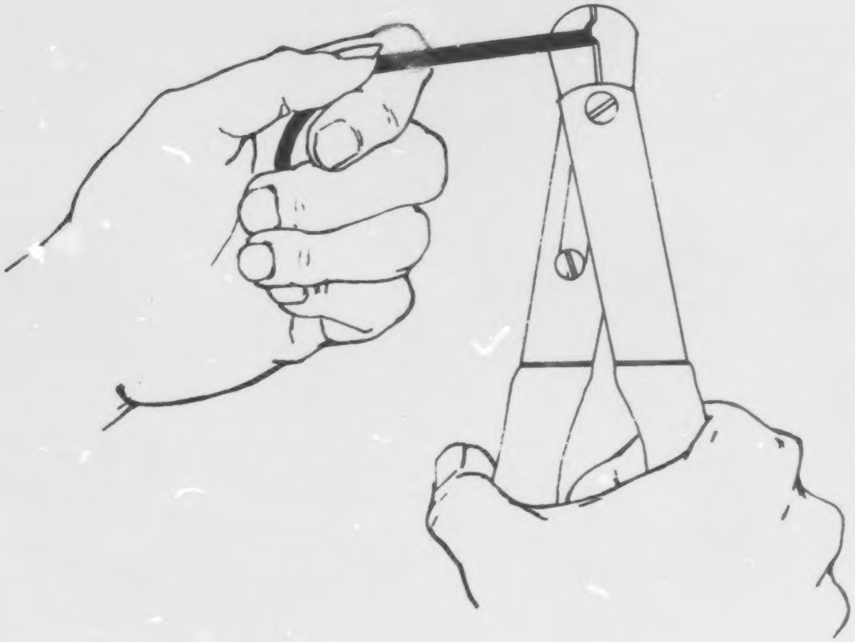
Component Lead Cleaner



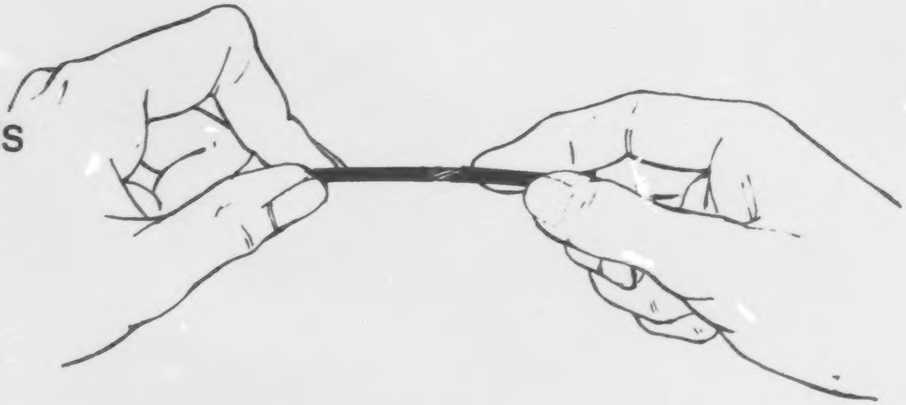
Typewriter Eraser Used To Mechanically Clean Parts To Be Soldered

Wire Stripping

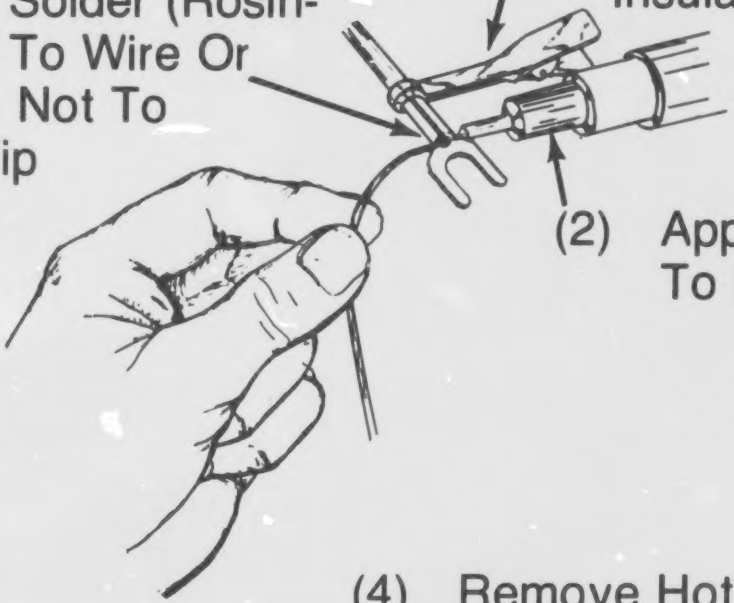
(1) With Wire In Proper Slot, Separate Insulation About ¼"



(2) Using Slight Twisting Action To Keep Strands Intact, Remove Insulation From Wire



Proper Soldering Technique



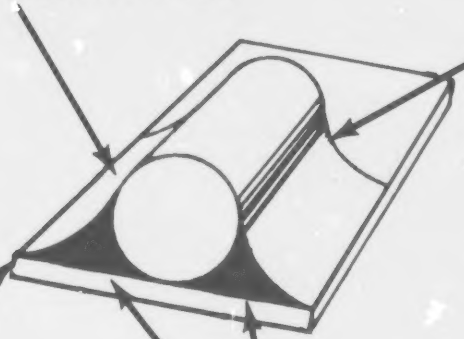
(1) Attach Heat Sink To Wire To Protect Insulation

(2) Apply Hot Iron Tip To Lug Or Terminal

(3) Apply Solder (Rosin-Core) To Wire Or Lug -- Not To Iron Tip

(4) Remove Hot Iron And Solder As Soon As Solder Has Flowed Freely Through And Around The Connection

A Good Solder Joint



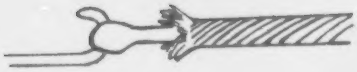
Shiny Surface Indicates Use of Sufficient Heat

Convex Angle of Solder Bead Shows Good Wetting

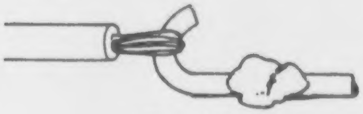
No Gaps Between Solder and Metal Surface Indicates Use of Sufficient Heat and Flux

Continuous Flow Over Full Surface Shows Good Wetting

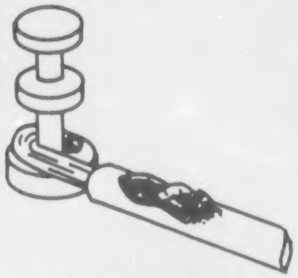
Poor Solder Connections



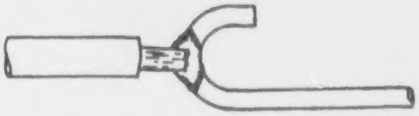
Insulation Damage



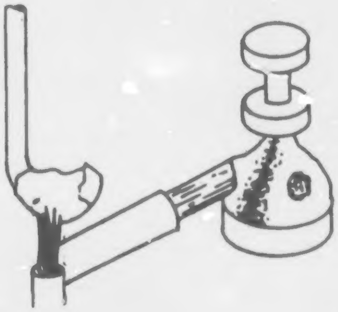
Solder Spill



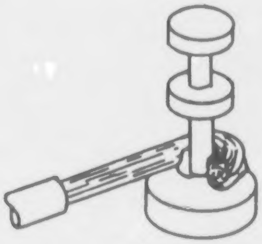
Damaged Insulation



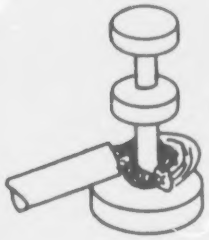
Insufficient Wire Wrap



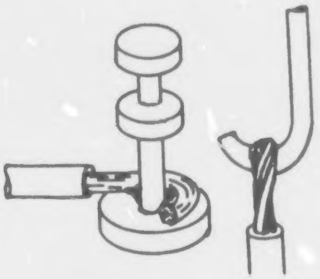
Excess Solder



Excessive Insulation Clearance



Insufficient Insulation Clearance



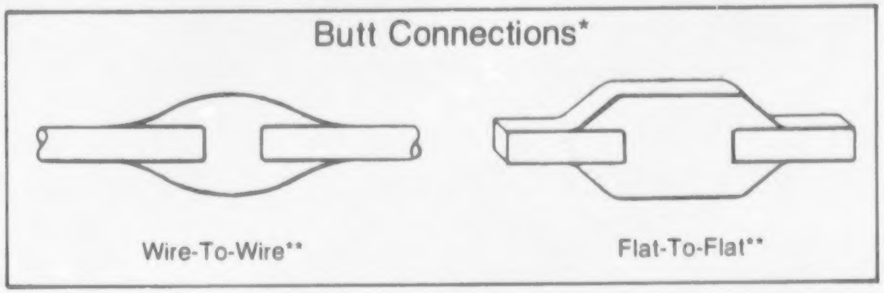
Insufficient Solder

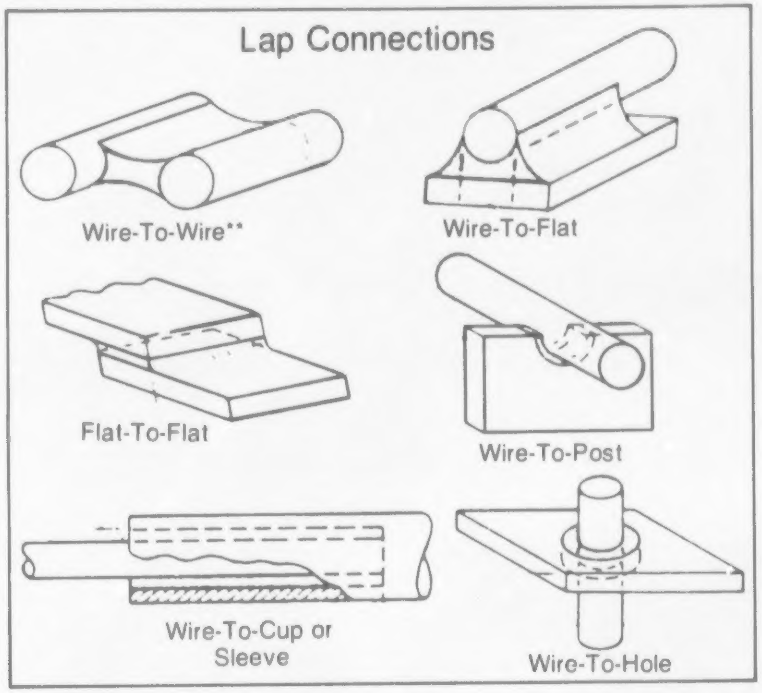
Appearance and Cause of Poor SolderJoints

Type Problem	Appearance	Cause
Cold Joint	Dull Silver Color; Poor Flow	Insufficient Heat
Disturbed Joint	Chalky or Crystallized; Poor Bond Between Solder and Surface	Connection Moved Before Solder Solidified
Dewetted Joint	Solder in Globular Form; Poor Bond at Interface	Insufficient Cleaning Insufficient Use of Flux
Burnt Insulation	Insulation Melted or Blackened	Excessive Heat Carelessness With Iron
Insulation Damage	End of Insulation Melted, Lifted, or Curled	Excessive Heat Excessive Application Time Lack of Heat Sink
Rosin Joint	Rosin Residue on Surface or In Joints of Connection	Excessive Rosin Insufficient Heat
Solder Short	Solder Bridges to Adjacent Connection or to Ground	Excessive Solder Carelessness When Applying Solder

Soldered Connections

No Mechanical Security Prior to Soldering


Butt Connections*
Wire-To-Wire**
Flat-To-Flat**


Lap Connections
Wire-To-Wire**
Wire-To-Flat
Flat-To-Flat
Wire-To-Post
Wire-To-Cup or Sleeve
Wire-To-Hole

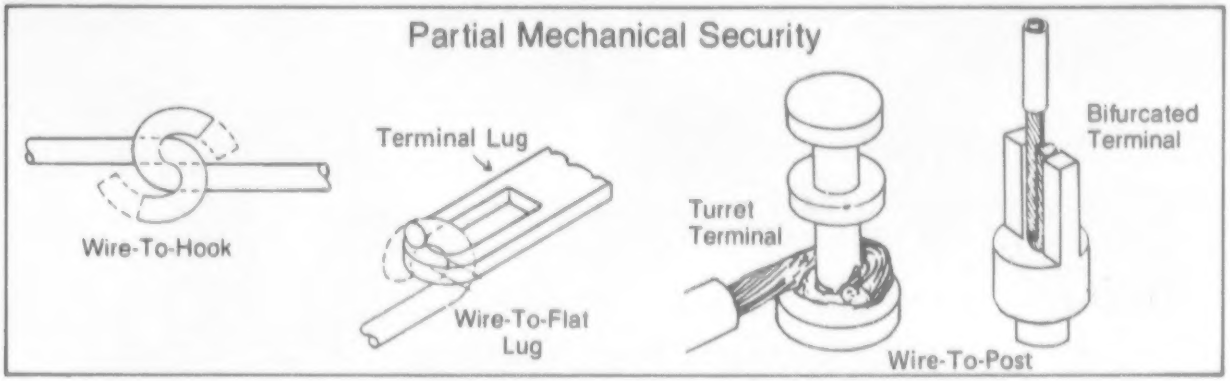
*Butt Connections are Seldom Used in Electrical Work

**These Connections Require a Fixture to Prevent Movement During Soldering

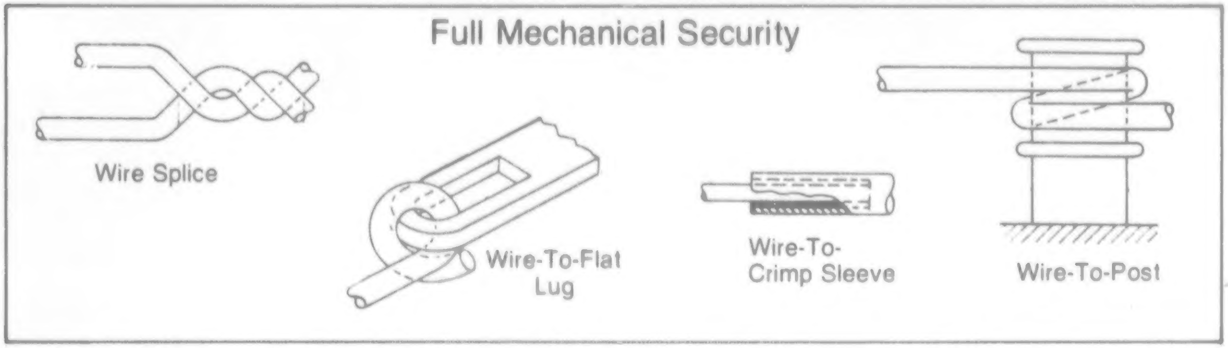
Soldered Connections

With Mechanical Security Prior to Soldering

Partial Mechanical Security


Wire-To-Hook
Terminal Lug
Wire-To-Flat Lug
Turret Terminal
Bifurcated Terminal
Wire-To-Post

Full Mechanical Security


Wire Splice
Wire-To-Flat Lug
Wire-To-Crimp Sleeve
Wire-To-Post

SOLDERING AND CIRCUIT FABRICATION
UNIT II

JOB SHEET #1--STRIP AND TIN WIRES FOR SOLDERED CONNECTIONS

I. Materials required

  A. Soldering iron

  B. 60/40 rosin core solder (18 gauge)

  C. Soldering iron holder

  D. Mechanical wire strippers

  E. 10 feet of 22-gauge stranded wire

  F. Acid brush

  G. Wire stripper

  H. Heat sink

II. Procedure

  A. Plug soldering iron into AC outlet

  B. As soon as the tip is hot, tin the iron tip; remove excess solder with a clean rag or paper towel

  C. Cut wire into 8-inch lengths

  D. Using mechanical wire strippers, strip about one inch of insulation from each end of each wire length

  E. Clean stripped wire ends with isopropyl alcohol and clean cloth

  F. Gently twist wire ends in direction of strand twist so that strands do not separate

  G. Place heat sink on stranded wire end as close as possible to end of wire insulation

  H. Place wire end on heated iron tip and apply solder until solder freely flows among all wire strands; remove wire and solder

  I. Remove heat sink

  J. Clean tinned wire using isopropyl alcohol and acid brush

JOB SHEET #1

K. Check that excessive solder has not been applied (outline of all strands should be visible through the solder) and that wire insulation shows no evidence of burning or wicking

L. Repeat tinning operation until all wire ends have been tinned

SOLDERING AND CIRCUIT FABRICATION
UNIT II

JOB SHEET #2--SOLDER WIRES TO TURRET TERMINALS, THEN DE-SOLDER WIRES

I. Materials required

A. Variac, for controlling soldering iron temperature (optional)

B. Soldering iron

C. Vise, for holding the terminal board during soldering

D. Heat sink

E. Wire strippers

F. Long nose or needle nose pliers

G. Rosin-core solder (22-gauge)

H. Isopropyl alcohol

I. Acid brush

J. Bakelite board with two turret terminals mounted on it approximately four inches apart

K. Two 8-inch lengths of 22-gauge stranded wire, stripped and tinned in accordance with Job Sheet #1

II. Procedure

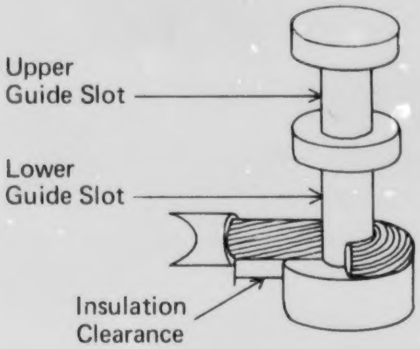
A. Secure bakelite board in vise so that terminals are accessible for soldering

B. Plug in soldering iron

JOB SHEET #2

C. Using pliers, form end of one wire around lower guide slot of one turret terminal as shown in Figure 1

FIGURE 1



(NOTE: Figure 1 shows the wire wrapped 180° around the turret terminal. If desired, the wire may be wrapped 360° around the terminal to make a more secure mechanical connection prior to soldering. However, this may require stripping and tinning a longer length of the wire end.)

D. Attach heat sink to wire insulation as close as possible to wire and without interfering with soldering operation

E. Using soldering iron and rosin-core solder, solder wire to terminal

F. Remove heat sink

G. Clean soldered connection with isopropyl alcohol and clean cloth or acid brush

H. Check that soldered connection is correct

I. Solder opposite end of wire to lower guide slot of second terminal in same manner (steps C through H)

J. Solder second length of wire to upper guide slots of terminals in same manner (steps C through H)

K. De-solder all connections as follows:

1. Apply hot iron tip to terminal to melt solder, and pry wire off terminal
2. While still applying hot iron tip, remove solder with a brush or solder sucker
3. Clean de-soldered terminal with isopropyl alcohol and clean cloth

SOLDERING AND CIRCUIT FABRICATION
UNIT II

JOB SHEET #3--SOLDER WIRES TO A TERMINAL STRIP

I. Materials required

  A. Soldering iron

  B. Vise, for holding the terminal strip during soldering

  C. Heat sink

  D. Chain or needle nose pliers

  E. Rosin-core solder (22-gauge)

  F. Isopropyl alcohol

  G. Typewriter eraser

  H. Acid brush

  I. Mounting strip with five or more terminals

  J. Five 8-inch lengths of 22-gauge stranded wire, stripped and tinned in accordance with Job Sheet #1

II. Procedure

  A. Clean terminals of oxides by means of typewriter eraser, and of dirt and grease by means of isopropyl alcohol and clean cloth

  B. Secure terminal strip in vise

  C. Plug in soldering iron

  D. Using pliers, mechanically attach tinned wire to first terminal; make sure end of insulation is approximately 1/16-inch from soldered connection

  (NOTE: It may be necessary to cut off excess wire so that the distance between the insulation and the connection is correct.)

  E. Attach heat sink to wire

  F. Solder wire to terminal

  G. Remove heat sink

  H. Clean soldered terminal by means of isopropyl alcohol and acid brush

JOB SHEET #3

I. Check that soldered connection is correct and that insulation is not burned

J. Repeat steps D through I for the other four connections, being careful not to touch adjacent wires with the hot iron

SOLDERING AND CIRCUIT FABRICATION
UNIT II

JOB SHEET #4--REPAIR A PRINTED CIRCUIT BOARD BY REPLACING RESISTORS AND CORRECTING OPEN OR BROKEN LANDS

I. Materials required

- A. Variac, to control soldering iron temperature
- B. Vise or clamp
- C. Soldering iron
- D. Solder sucker
- E. Nail clippers
- F. Isopropyl alcohol
- G. 60/40 rosin-core solder (22-gauge)
- H. Typewriter eraser
- I. Acid brush
- J. Chain nose pliers
- K. Component lead cleaner
- L. Printed circuit board with two damaged resistors, an open conducting path, and a broken or removed land
- M. Two replacement resistors

II. Procedure

- A. Plug soldering iron into variac and set voltage at 90-95 volts (for 30-watt iron)
- B. Remove damaged component by clipping component leads
- C. Turn board over
- D. Remove remaining lengths of component leads by heating solder and lifting leads off board by means of chain nose pliers; remove melted solder by means of solder sucker
- E. Remove grease and rosin from connections by means of isopropyl alcohol and acid brush
- F. Remove oxides from the land by means of the typewriter eraser

JOB SHEET #4

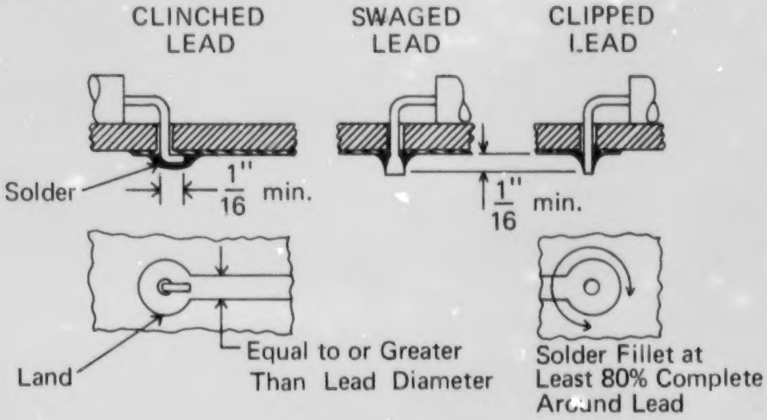
G. Clean oxides from replacement component leads by means of component lead cleaner

H. Measure distance between component land connections and bend component leads at right angles so that the leads will insert into the land eyelets

I. Insert component leads into land holes so that component lies on upper surface of board

J. While holding component in place, turn board over and either clinch, swage, or clip component leads as shown in Figure 1

FIGURE 1


CLINCHED LEAD
SWAGED LEAD
CLIPPED LEAD
Solder
1"/16 min.
1"/16 min.
Land
Equal to or Greater Than Lead Diameter
Solder Fillet at Least 80% Complete Around Lead

(NOTE: Clinching provides the best mechanical connection. The leads are swaged or clipped when space limitations prevent clinching. If the leads are to be clipped, it may be best to postpone the clipping operation until after the connections have been soldered.)

K. Install board in clamp or vise

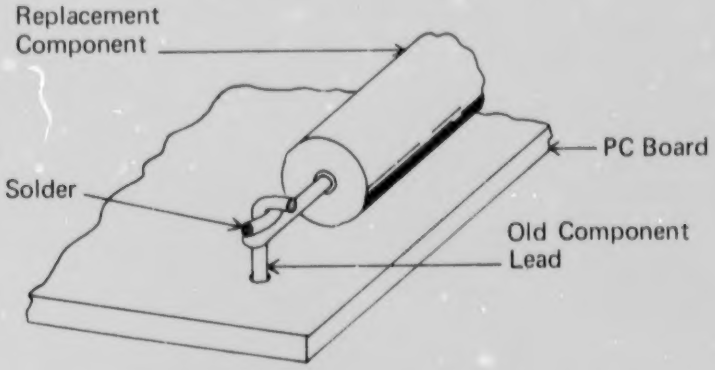
L. Attach heat sink to component lead at each end of component

M. Solder component lead to land at each connection as shown in Figure 1

JOB SHEET #4

N. Replace second resistor by cutting off damaged resistor as before, but soldering new resistor to old component leads as shown in Figure 2

FIGURE 2

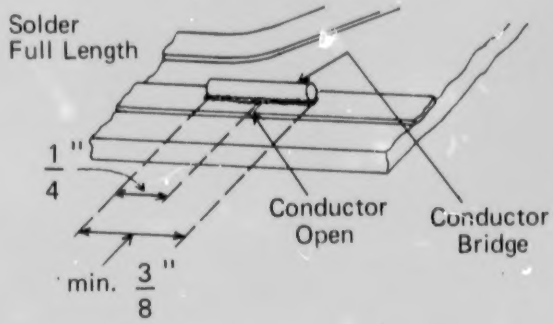

Replacement Component
PC Board
Solder
Old Component Lead

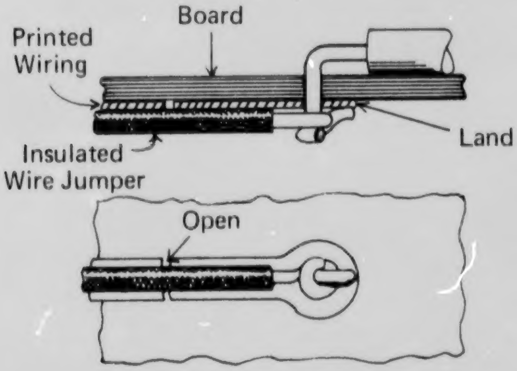
O. Repair open in printed wiring by soldering a conductor bridge across the open using one of the techniques shown in Figure 3

FIGURE 3

Solder Conductor Bridge Across Open as Shown

...or...


Solder Full Length
1/4 "
min. 3/8 "
Conductor Open
Conductor Bridge

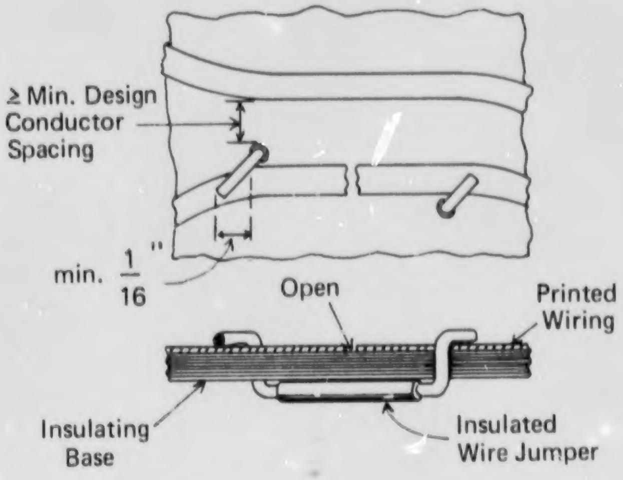

Board
Printed Wiring
Insulated Wire Jumper
Land
Open

Solder Insulated Wire Jumper Across Open on Conductor Side of Board

...or...

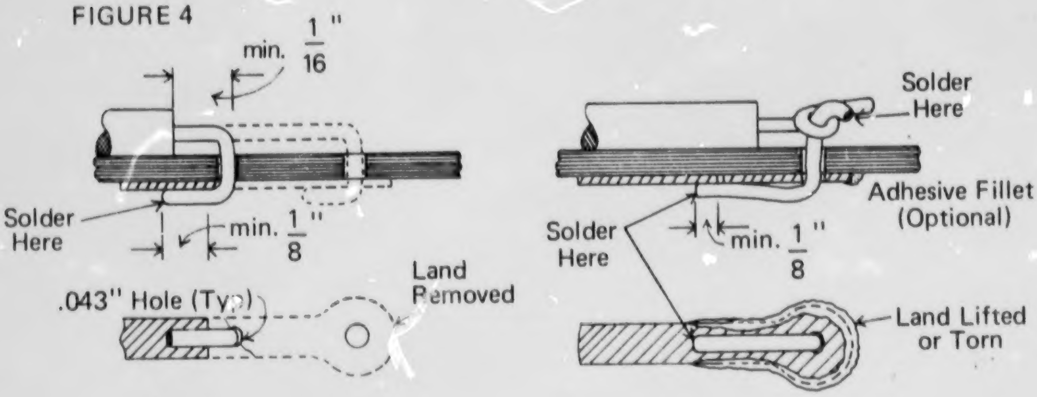
JOB SHEET #4

Solder Insulated Wire Jumper Across Open on Component Side of the Board


≥ Min. Design Conductor Spacing
min. 1/16"
Open
Printed Wiring
Insulating Base
Insulated Wire Jumper

P. Repair removed or lifted land as shown in Figure 4

FIGURE 4


min. 1/16"
Solder Here
min. 1/8"
.043" Hole (Typ)
Land Removed
Solder Here
Adhesive Fillet (Optional)
Solder Here
min. 1/8"
Land Lifted or Torn

Q. Check all soldered connections for proper configuration

R. Check that no solder has been spilled to cause possible shorts with adjacent connections or wiring

S. Clean all soldered connections with isopropyl alcohol and acid brush

SOLDERING AND CIRCUIT FABRICATION
UNIT II

JOB SHEET #5--SPLICE WIRES TOGETHER BY MEANS OF SOLDERING AND CRIMPING (FLAT CABLE)

I. Materials required

A. Soldering iron

B. Crimping tool

C. 18 inches of #26 stranded wire

D. 24 inches of #20 wire

E. One splice lug for #20 wire

F. Two inches of shrink tubing for #26 wire

G. Electrical tape

II. Procedure

A. Cut the #26 wire into three equal lengths

B. Strip, clean, and tin one end of each length

C. Cut the #20 wire into four equal lengths

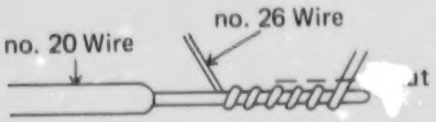
D. Strip, clean, and tin one end of each length

E. Trim tinned ends of all wires to 1/2 inch length

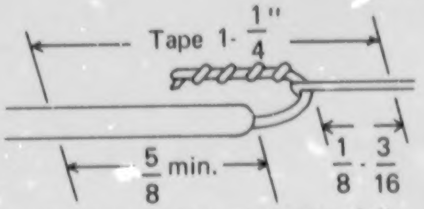
JOB SHEET #5

F. Splice tinned ends of one #20 wire and one #26 wire (Figure 1)

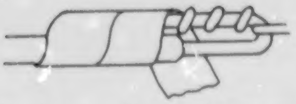
FIGURE 1


no. 26 Wire
no. 20 Wire
ut

1. Wrap smaller wire around larger wire


Tape 1-$\frac{1}{4}$"
$\frac{5}{8}$ min.
$\frac{1}{8}$ - $\frac{3}{16}$

2. Bend wires back and solder full length of twist

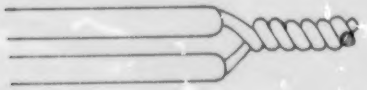


3. Apply electrical tape over splice

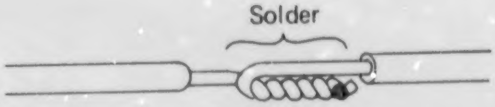
G. Install shrink tubing on one length of #26 wire

H. Splice tinned ends of two lengths of #26 wire (including the one with the tubing) (Figure 2)

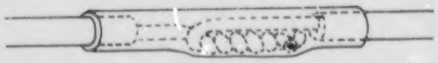
FIGURE 2



1. Twist wires together



2. Solder twisted ends



3. Slide heat shrink tubing over splice

JOB SHEET #5

I. Shrink the tubing by passing the hot soldering iron back and forth across the length of the tubing, WITHOUT TOUCHING THE TUBING

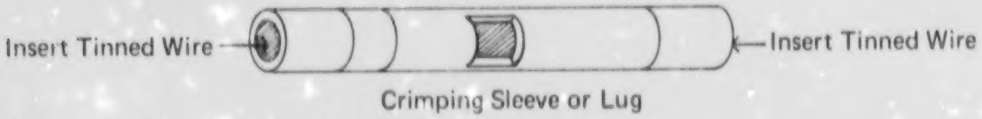
J. Continue applying heat until tubing fits snugly over the splice

K. Insert tinned ends of two lengths of #20 wire in opposite ends of crimping lug (Figure 3); make sure strands of both wires are visible in slot at center of lug

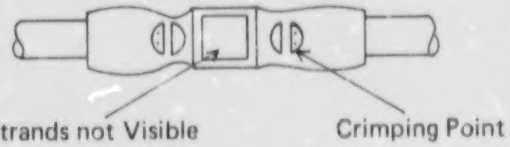
L. Using crimping tool, crimp both ends of lug

M. Check that crimp is correct (Figure 3)

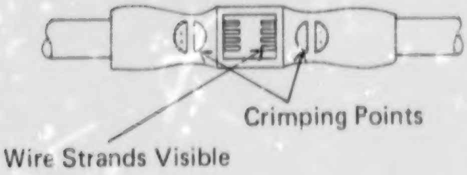
FIGURE 3


Insert Tinned Wire
Insert Tinned Wire
Crimping Sleeve or Lug

INCORRECT CRIMP


Wire Strands not Visible
Crimping Point

CORRECT CRIMP


Crimping Points
Wire Strands Visible

SOLDERING AND CIRCUIT FABRICATION
UNIT II

JOB SHEET #6--CONNECT ENDS OF FLEXIBLE PRINTED WIRING (FLAT CABLE)

I. Material required

- A. Soldering iron
- B. 60/40 rosin-core solder
- C. Thermal wire stripper
- D. Length of flexible printed wiring (flat cable)
- E. 5-pin male connector
- F. Printed circuit board with five adjacent printed conductors

II. Procedure

- A. Strip insulation from one end of cable as follows (Figures 1 and 2)

FIGURE 1

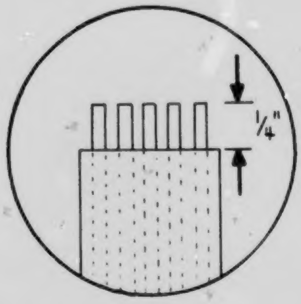
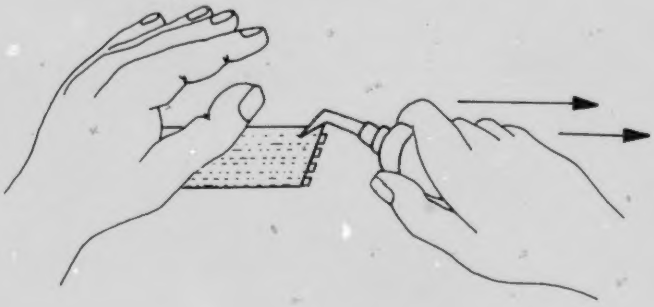


FIGURE 2



1. Scribe line on printed wiring 1/4-inch back from straight end
2. Place printed wiring on flat heat-resistant surface and hold wiring in place with heel of one hand

JOB SHEET #6

3. Connect thermal stripper to power source

4. When stripper is hot enough to melt insulation, melt and peel insulation from cable by pulling stripper from scribe line toward end of wiring as shown in Figure 2

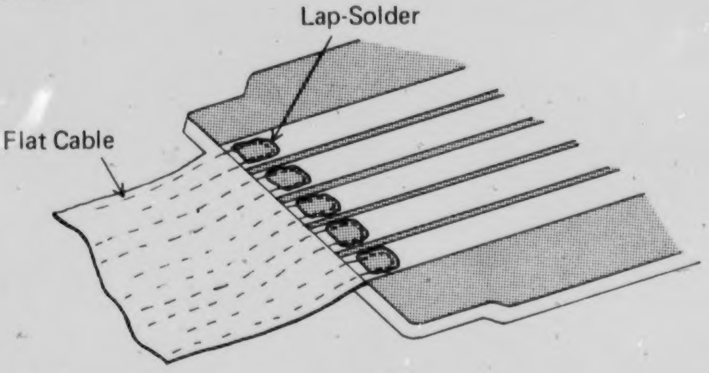
   (CAUTION: If a power supply is being used to provide power to the stripper, the stripper should be turned off periodically. Thermal wire strippers draw high current, and prolonged high current may damage the power supply.)

5. Turn wire over and strip opposite side in same manner; turn off stripper

B. Clean and tin stripped conductors of flexible wiring and conductors of printed circuit board to which they will be connected

C. Lap-solder conductors of flexible wiring to conductors of printed circuit board as shown in Figure 3

FIGURE 3

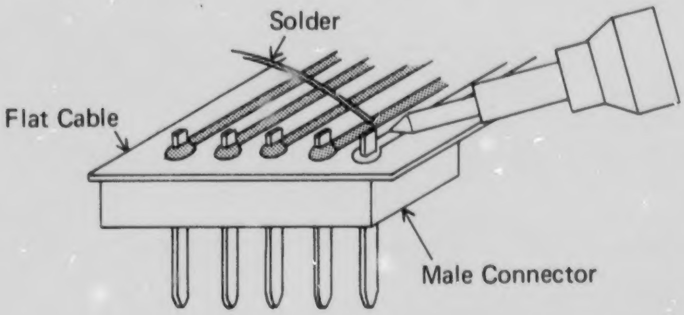


D. Clean and tin pins of male connector, and eyelets at opposite end of flexible printed wiring

JOB SHEET #6

E. Insert pins of male connector in eyelets of flexible wiring as shown in Figure 4

FIGURE 4


Solder
Flat Cable
Male Connector

F. Solder pins to flat cable eyelets as shown

SOLDERING AND CIRCUIT FABRICATION
UNIT II

NAME_______________________________

TEST

1. Match the terms on the right with their definitions.

______a. Applying mechanical pressure to compress a sleeve-type or cup-type electrical terminal to ensure a good electrical connection between the sleeve and the conducting wire it contains

______b. The application of a small amount of solder to surfaces to be soldered to help ensure good wetting during soldering

______c. Films and impurities which form on the surface of metals when exposed to air or water and which, if not cleaned off, will prevent a good bond between the surfaces and solder

______d. Printed wiring attached to the surface of a printed circuit board

______e. A material obtained from pine trees which is used during soldering to help ensure a good bond between the solder and the metal surfaces

______f. Removing insulation from electrical conductors

______g. The ability of molten solder to flow over and fuse completely with the metal surfaces to which it is applied

______h. A liquid or solid which when heated cleans and protects surfaces to be soldered

1. Oxides
2. Rosin
3. Wetting
4. Stripping
5. Tinning
6. Flux
7. Crimping
8. Land

2. Match the soldering tools and materials on the right with the correct uses.

______a. For soldering large electrical connections

______b. For soldering small electrical connections

______c. For soldering large electrical connections where better heat control is required

______d. For soldering many connections in close spaces

1. Thermal wire strippers
2. Component lead cleaner
3. Solder sucker
4. Resistance soldering unit

_____e. For drawing heat from soldered connection to prevent damage to components

_____f. For removing oxides and other films from component leads

_____g. For removing oxides and other films from terminals to be soldered

_____h. For removing oil, grease, and flux from conductors and terminals both before and after soldering

_____i. For cutting and pulling insulation from ends of conductors

_____j. For removing wire insulation by heating and melting the material; prevents removing wire strands, but cannot be used on insulation that will not melt, such as glass braid or asbestos

_____k. For making electrical connections; most common type is 60/40 rosin-core solder containing 60% tin and 40% lead, with a center core of rosin flux to allow simultaneous application of both solder and flux

_____l. For making mechanical connection prior to soldering; may also be used as heat sink during soldering

_____m. For cutting conductors

_____n. For supporting a hot soldering iron when not in use

_____o. For clamping and holding a printed circuit board or other component during soldering or other repair operations

_____p. For ensuring a good electrical connection by cleaning and wetting all surfaces during soldering; not required if the solder contains a rosin core

_____q. For controlling soldering iron tip temperature

_____r. For making a strong mechanical connection to certain sleeve-type terminals

5. Crimping tool
6. Soldering iron, 100 watt
7. Typewriter eraser
8. Soldering vise
9. Isopropyl alcohol
10. Soldering pencil, 10 to 35 watts
11. Diagonal cutting pliers
12. Spaghetti-sleeve insulation
13. Mechanical wire strippers
14. Soldering gun, 100 watts
15. Solder
16. Adjustable power source
17. Heat shrink insulation
18. Heat sink
19. Long nose and needle nose pliers
20. Flux
21. Soldering iron stand

______s. For preventing electrical connections from becoming shorted to adjacent connections

______t. For removing melted solder from a terminal to be resoldered

______u. Sleeve-type insulation which, when heated, shrinks to form a snug fit over a soldered connection

3. Select true statements about cleaning before and after soldering by placing an "X" to the left of the true statements.

______a. To remove oil, grease, and dirt, wipe with isopropyl alcohol and clean cloth

______b. To remove old solder, heat with a soldering iron and wick away, or suck up by means of a solder sucker

______c. Use a typewriter eraser to clean oxides from terminals

______d. To remove rosin flux, wipe or brush with glycerine water

4. Select the true statements about wire stripping and tinning by placing an "X" in the appropriate blanks.

______a. One slot in the wire strippers is used for all size wires

______b. Care must be taken not to remove wire strands when stripping

______c. After stripping, clean the wire strands with isopropyl alcohol and paper towel

______d. Place heat sink on wire strands immediately adjacent to wire insulation before tinning

______e. Tinning applies only to the stripped wire, not to the soldering iron tip

______f. After tinning, the wire strands should not be visible through the solder

______g. After solder has cooled, clean the tinned wire with isopropyl alcohol and paper towel

5. Select the true statements about soldering procedures by placing an "X" in the appropriate blanks.

______a. It is not necessary to clean surfaces prior to soldering

______b. Strip and tin wires to be soldered

______c. A small 35-watt soldering iron should be used for all electrical soldered connections ______d. The heat sensitivity of components is an important factor to consider when choosing a soldering iron

______e. If mechanical connection is not possible, make sure component to be soldered is held stationary in vise or clamp to prevent movement during soldering

______f. The following is the correct soldering procedure: Apply hot iron tip to terminal and wire, and apply solder to iron tip so that it will flow down onto the connection

______g. The following is the correct soldering procedure: Apply hot iron tip to terminal and wire, and apply solder to wire, or component lead or terminal

______h. Movement of the wire while the solder solidifies will cause no harm

______i. After the solder has cooled, the connection should be cleaned with isopropyl alcohol

6. Select the characteristics of a good solder connection by placing an "X" in the appropriate blanks.

______a. Silvery, shiny appearance to solder surface

______b. Dull appearance

______c. Damaged insulation

______d. No burnt areas on insulation

______e. Gap between insulation and connection is approximately 3/4"

______f. Good wetting of solder to surfaces

______g. Solder does not have to completely cover connection

______h. Small pits or holes in solder surface

______i. Solder spills

______j. Gap between insulation and connection is approximately the diameter of the wire insulation

______k. Solder completely covers connection, but contour of connection is still visible

7. Match the types of poor solder connections on the right with their causes.

______a. Insufficient heat

______b. Connection moved before solder solidified

1. Burnt insulation
2. Dewetted solder joint

_____c. Too much solder applied

_____d. Too little solder applied

_____e. Insufficient cleaning or insufficient use of flux

_____f. Excessive heat or carelessness with iron

_____g. Excessive heat applied, excessive iron application time, or lack of heat sink

_____h. Excessive rosin or insufficient heat

_____i. Excessive solder or carelessness

3. Excessive solder
4. Solder short
5. Insufficient solder
6. Disturbed joint
7. Insulation damage
8. Rosin solder joint
9. Cold solder joint

8. Name two types of soldered connections for the degrees of mechanical security required prior to soldering.

   a. No mechanical connection prior to soldering

      1) Butt connections

         a) _______________

         b) _______________

      2) Lap connections

         a) _______________

         b) _______________

   b. Partial mechanical connection prior to soldering

      1) _______________

      2) _______________

   c. Full mechanical connection prior to soldering

      1) _______________

      2) _______________

9. Demonstrate the ability to:

   a. Strip and tin wire for soldered connections.

   b. Solder wires to turret terminals, then de-solder wires.

   c. Solder wires to a terminal strip.

d. Repair a printed circuit board by replacing resistors and correcting open or broken lands.

e. Splice wires together by means of soldering and crimping.

f. Connect ends of flexible printed wiring.

(NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

SOLDERING AND CIRCUIT FABRICATION
UNIT II

ANSWERS TO UNIT TEST

1.

a.	7	d.	8	g.	3
b.	5	e.	2	h.	6
c.	1	f.	4		

2.

a.	6	f.	2	k.	15	p.	20	u.	17
b.	10	g.	7	l.	19	q.	16		
c.	14	h.	9	m.	11	r.	5		
d.	4	i.	13	n.	21	s.	12		
e.	18	j.	1	o.	8	t.	3		

3. a, b, c

4. b, c, d, g

5. b, d, e, g, i

6. a, d, f, j, k

7.

a.	9	d.	5	g.	7
b.	6	e.	2	h.	8
c.	3	f.	1	i.	4

8. Any two of the following under each degree of mechanical security required prior to soldering:

   a. No mechanical connection prior to soldering

      1) Butt connections
         a) Wire-to-wire
         b) Flat-to-flat

      2) Lap connections
         a) Wire-to-wire
         b) Wire-to-flat
         c) Flat-to-flat
         d) Wire-to-post
         e) Wire-to-cup or sleeve
         f) Wire-to-hole

   b. Partial mechanical connection prior to soldering

      1) Wire-to-hook
      2) Wire-to-flat lug
      3) Wire-to-turret or post

   c. Full mechanical connection prior to soldering

      1) Wire spliced to wire
      2) Wire to flat lug
      3) Wire to turret or post
      4) Wire to crimp sleeve

9. Performance skills evaluated to the satisfaction of the instructor.

SCIENTIFIC CALCULATIONS
UNIT III

UNIT OBJECTIVE

After completion of this unit, the student should be able to use an electronic calculator, convert numbers between binary and decimal systems, and express numbers in scientific and engineering notation. The student should also be able to obtain trigonometry function values and determine logarithms of numbers. This knowledge will be evidenced by correctly performing the procedures outlined on the assignment sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms associated with scientific calculations with the correct definitions.
2. Match data keys of an electronic calculator with their functions.
3. Match function keys of an electronic calculator with their functions.
4. Match the major categories of the number system with the correct definitions.
5. Select true statements concerning systems of numeration.
6. Express a large number and a decimal fraction in scientific notation.
7. State the laws of exponents when multiplying and dividing.
8. Arrange in order the operations of computation.
9. Match trigonometry functions with the correct statements which describe them.
10. Demonstrate the ability to:
    a. Use an electronic calculator.
    b. Solve combined multiplication and division problems.
    c. Convert numbers between binary and decimal systems.
    d. Express numbers in scientific and engineering notation.
    e. Obtain trigonometry function values.
    f. Determine logarithms of numbers.

SCIENTIFIC CALCULATIONS
UNIT III

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information and assignment sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information and assignment sheets.

VI. After students are familiar with hand-held electronic calculators, visits to engineering, scientific, and business computer centers are suggested.

VII. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:
   A. Objective sheet
   B. Information sheet
   C. Transparency masters
      1. TM 1--Electronic Calculator Typical Keyboard
      2. TM 2--The Number System
      3. TM 3--Decimal System of Numeration
      4. TM 4--Binary System of Numeration
      5. TM 5--Trigonometry Functions
   D. Assignment sheets
      1. Assignment Sheet #1--Use an Electronic Calculator
      2. Assignment Sheet #2--Solve Combined Multiplication and Division Problems
      3. Assignment Sheet #3--Convert Numbers Between Binary and Decimal Systems
      4. Assignment Sheet #4--Express Numbers in Scientific and Engineering Notation

5. Assignment Sheet #5--Obtain Trigonometry Function Values

6. Assignment Sheet #6--Determine Logarithms of Numbers

E. Answers to assignment sheets

F. Test

G. Answers to test

II. References:

A. Carney, Richard. *Your Electronic Hand Calculator--How to Get the Most Out of It.* New Brunswick, NJ: Rutgers University, 1978.

B. *Personal Programming.* Dallas, TX: Texas Instruments Inc., 1977.

SCIENTIFIC CALCULATIONS
UNIT III

INFORMATION SHEET

I. Terms and definitions

A. Data keys--Keys that enter, change, or erase numbers

B. Function keys--Keys that perform mathematical operations, or that move data from one register to another.

C. Register--Locations in a calculator (computer) where numbers are placed for processing

Examples: Display Register, Data Register, or Memory Register

D. Logarithm--The exponent to which a base is raised to give a particular number

Example: The logarithm of 100 to the base of 10 is 2, because 10^2 equals 100

E. Reciprocal--One of a pair of numbers whose product is one

Example: $\frac{3}{2}$ is the reciprocal of $\frac{2}{3}$ because $\frac{3}{2} \times \frac{2}{3} = 1$

F. Scientific notation--The expressing of numbers as the product of a number between 1 and 10, and an appropriate power of 10

Example: 12345.6 in scientific notation is 1.23456×10^4

G. Engineering notation--Expressing numbers as the product of a number between 1 and 1000 and a power of 10 which is a multiple of 3

Example: 12345.6 in engineering notation is 12.3456×10^3

H. Significant digits--The digits in a number (usually from measurement) considered to be reliable

II. Data keys on an electronic calculator and their functions (Transparency 1)

(NOTE: Your calculator may not agree exactly with this list.)

A. $\boxed{0}$ through $\boxed{9}$ --Digit keys

B. $\boxed{.}$ --Decimal point

C. $\boxed{\pi}$ --Pi (3.14159...)

D. $\boxed{+/-}$ --Change sign key

E. $\boxed{C}$ --Clear or erase numbers in the display or storage register

F. $\boxed{EE}$ or $\boxed{Exp}$ or $\boxed{E\ ex}$ --Enter exponent

INFORMATION SHEET

III. Function keys on an electronic calculator (Transparency 1)

A. + --Add the next number

B. - -Subtract the next number

C. x --Multiply by next number

D. ÷ -Divide by next the number

E. % --Change percentage number to a decimal

Example: 6% to .06

F. = --Complete the arithmetic and display the answer

G. 1/x --Calculate reciprocal of number in display

H. x^2 --Square the number in display

I. $\sqrt{x}$ -Calculate square root of number in display

J. lnx --Calculate natural logarithm (to base e = 2.718281...)

K. log --Calculate common logarithm (to base 10)

L. sin --Calculate the sine of number in display

M. cos --Calculate the cosine of number in display

N. tan --Calculate the tangent of number in display

O. Deg --Places calculator in degree mode (rather than radians)

P. K -Constant key used for repetitive operations

Q. y^x --The base y to the x power

R. STO --Store in memory

S. RCL --Recall from memory

T. SUM --Sum value in display into memory

U. EXC --Exchange value in display with value in memory

V. ( ) -Grouping (parenthesis) to insure correct order of arithmetic operations

W. INV --Inverse key which reverses the purpose of the next key pressed

Example: INV SUM 1 will subtract rather than add number in display to memory register no. 1

INFORMATION SHEET

IV. Major categories of the number system and their descriptions (Transparency 2)

A. Non-negative integers--Includes zero and positive integers

B. Zero--A non-negative integer which is neither positive or negative

C. Positive integers--The counting numbers or whole numbers of arithmetic

D. Integer--Includes non-negative integers and negative integers

E. Fractions--Expressed in the form p/q where q is not equal to zero and q does not divide evenly into p

F. Rational numbers--Includes integers and fractions

(NOTE: A rational number can be expressed in the form p/q and includes both terminating and repeating decimals.)

Examples: Terminating decimals: 7/8 or .875
Repeating decimals: 1/3 or .3333.., 41/333 or .123123123...

G. Real numbers--Includes rational numbers and irrational numbers

H. Irrational numbers--Numbers which cannot be expressed in the form p/q

Examples: Pi, e, $\sqrt{2}$

I. Complex numbers--Includes real numbers and imaginary numbers

(NOTE: Complex numbers are of the form a + jb, where a and b are real numbers and j x j = -1. Mathemeticians use "i" rather than "j", but in electronics "j" is more commonly used. "J" is also called the "j operator." When b (in the expression a + jb) equals 0, the number is real.)

V. Systems of numeration

A. Decimal system of numeration (Transparency 3)

1. Base is 10
2. There are 10 digits (1, 2, 3, 4, 5, 6, 7, 8, 9, and 0)
3. Digits have place value
4. Position placement of a digit is 10 times greater in one position than in the position on its right

INFORMATION SHEET

B. Binary system of numeration (Transparency 4)

1. Base is 2
2. There are 2 digits (0, and 1)
3. Digits have place value
4. Position placement of a digit is 2 times greater than position on right

VI. Expressing numbers in scientific notation

A. Move decimal to create number between 1 and 10

Example: 12300 to 1.23

B. Number of places decimal is moved gives exponent to be used

(NOTE: In example above, exponent is 4.)

C. Left movement of decimal gives a positive exponent; right a negative

(NOTE: In example above, decimal is moved to the left.)

D. Rewrite number as a product of a number between 1 and 10 and the correct power of 10

Examples: $12300 = 1.23 \times 10^4$

$.00256 = 2.56 \times 10^{-3}$

$943{,}000{,}000 = 9.43 \times 10^8$ (also equals 943×10^6 in engineering notation)

VII. The laws of exponents when multiplying and dividing

A. Law of exponents when multiplying: add exponents

$(B^m \times B^n) = B^{(m+n)}$ or $B^4 \times B^6 = B^{10}$

(NOTE: Observe that the same number, B, is used throughout.)

B. Law of exponents when dividing: subtract exponents

$$\frac{B^m}{B^n} = B^{(m-n)}$$

(NOTE: $B^m \times B^{-n} = B^{(m-n)}$.) .

INFORMATION SHEET

VIII. Order of operations of computation

(NOTE: This is not the order of entry when using calculators.)

A. When parenthesis are present, perform the operations within the parenthesis

B. Raise each base to power indicated (including roots)

C. Multiply and divide in order from left to right

D. Add and subtract in order from left to right

IX. Trigonometry functions (Transparency 5)

A. Sine function (sin θ)

1. In right triangle, is ratio of opposite side to hypotenuse
2. In unit circle, is length of opposite side (vertical distance)
3. Sine values range from -1 to +1

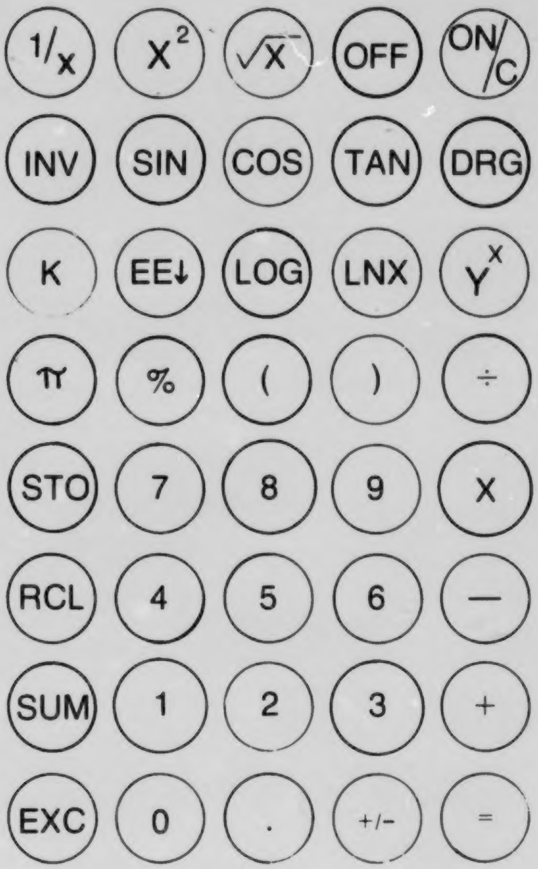
B. Cosine function (cos θ)

1. In right triangle, is ratio of adjacent side to hypotenuse
2. In unit circle, is length of adjacent side (horizontal distance)
3. Cosine values range from -1 to +1

C. Tangent function (tan θ)

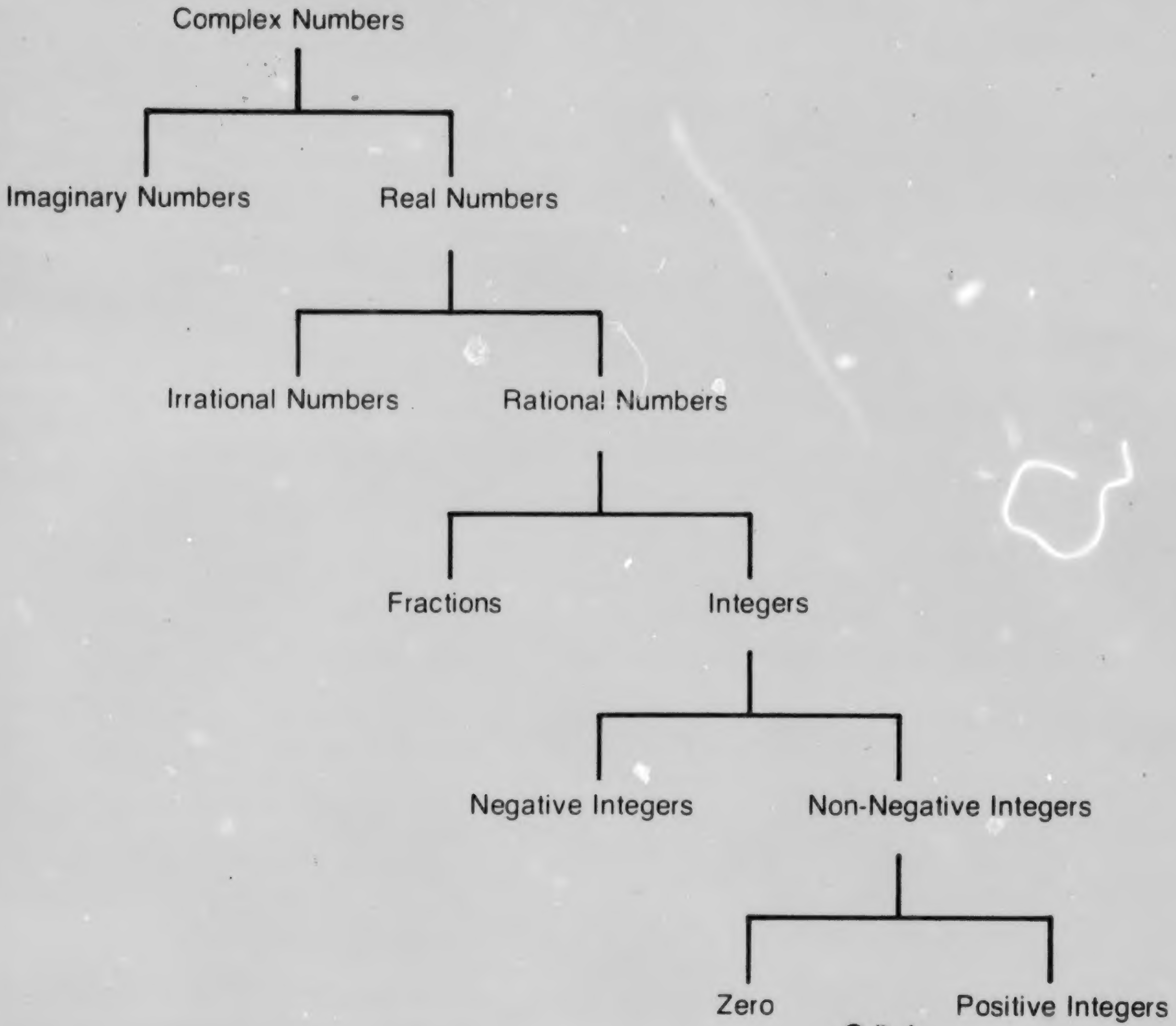
1. In right triangle, is ratio of opposite side to adjacent side
2. In unit circle, is length of tangent line to extended radius
3. Tangent values can be any real number

Electronic Calculator Typical Keyboard



$1/x$	X^2	$\sqrt{X}$	OFF	ON/C
INV	SIN	COS	TAN	DRG
K	EE↓	LOG	LNX	Y^X
π	%	(	)	÷
STO	7	8	9	X
RCL	4	5	6	—
SUM	1	2	3	+
EXC	0	.	+/-	=

The Number System


Complex Numbers
Imaginary Numbers
Real Numbers
Irrational Numbers
Rational Numbers
Fractions
Integers
Negative Integers
Non-Negative Integers
Zero
Positive Integers

Decimal System of Numeration

Digits(d) of Number:	- - -	$\underline{d_3}$	$\underline{d_2}$	$\underline{d_1}$	$\underline{d_0}$	.	$\underline{d_{-1}}$	$\underline{d_{-2}}$	- - -
Position Value: (Base 10)		10^3	10^2	10^1	10^0 (or 1)		10^{-1}		
Value Multiplier (Of Example)		6	4	7	2				

Example: $\underline{6472}_{\text{Base 10}}$

$$= (6 \times 10^3) + (4 \times 10^2) + (7 \times 10^1) + (2 \times 10^0)$$

$$= 6000 + 400 + 70 + 2$$

Binary System of Numeration

Digits(d) of Number:	- - -	d_4	d_3	d_2	d_1	d_0	$\cdot$	d_{-1}	d_{-2}	- - -
Position Value: (Base 2)	- - -	2^4	2^3	2^2	2^1	2^0 (or 1)		2^{-1}	2^{-2}	- - -
Value Multiplier (Of Example)			1	1	0	1				

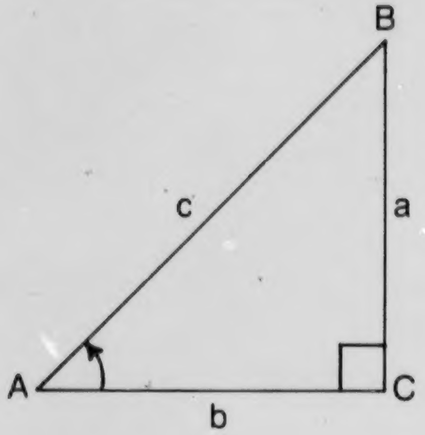
Example: $\underline{1101}_{\text{Base 2}}$

$$= (1 \times 2^3) + (1 \times 2^2) + (0 \times 2^1) + (1 \times 2^0)$$

$$= \text{(In Base 10) } 8 + 4 + 0 + 1 \text{ or } 13_{\text{Base 10}}$$

Trigonometry Functions

Right Triangle

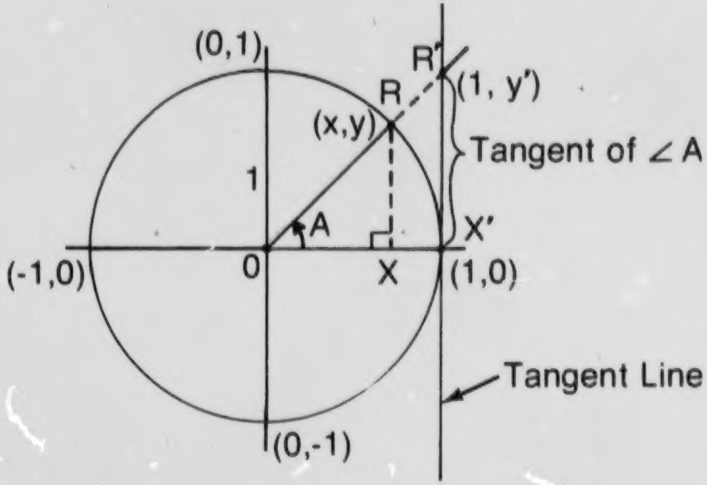


$$\text{Sin A} = \frac{a}{c} = \frac{\text{Opposite Side}}{\text{Hypotenuse}}$$

$$\text{Cos A} = \frac{b}{c} = \frac{\text{Adjacent Side}}{\text{Hypotenuse}}$$

$$\text{Tan A} = \frac{a}{b} = \frac{\text{Opposite Side}}{\text{Adjacent Side}}$$

Unit Circle


(0,1)
R'
(1, y')
R
(x,y)
Tangent of ∠ A
1
A
X'
(-1,0)
0
X
(1,0)
Tangent Line
(0,-1)

$$\text{Sin A} = \overline{RX}$$

$$\text{Cos A} = \overline{OX}$$

$$\text{Tan A} = \overline{X'R'}$$

SCIENTIFIC CALCULATIONS
UNIT III

ASSIGNMENT SHEET #1--USE AN ELECTRONIC CALCULATOR

(NOTE: Your particular calculator may differ from others and you may or may not be able to do all of the problems listed. Check with your instructor when in doubt.)

1. My calculator is manufactured by ____________________ and is Model No ______.

2. The power supply is ____________________ (type of batteries) and (can cannot) operate on AC.

3. Check your display by entering $\boxed{+/-}$ $\boxed{.}$ then "8's" until display is full. You should have "-.8888888" in the display. The number of digits my display holds is ________ and all digits are ok. yes _____ no _____

4. Adding and subtracting: *Remember:* $(A + B) = (B + A)$; $(A - B) = (-B + A)$ *but* $(A - B) \neq (B - A)$

   A. 102 + 345 = __________

   B. 678 - 109 = __________

   C. -782 + 386 + 1052 = (Enter in order shown) ___________

   D. 0.00312 + 1.0157 - 0.00235 = ____________

5. Multiplying and dividing: *Remember:* $(A \times B) = (B \times A)$; $(A/B = A \times 1/B)$

   A. 15 x 2 = __________

   B. 5766 ÷ 93 x 4 ÷ 16 = __________

   C. 49÷7÷0 = __________

   (NOTE: Many calculators display "flash" when given an instruction it can not perform. How did yours react when asked to divide by "0" in this problem? __________________________)

   D. 8.936/2 = _________ (Work this one of two ways: (1) 8.936÷2, or (2) $\boxed{1/x}$ x 8.936)

   E. .00325 x .0004 = _________

   In this problem deliberately enter .0005 as the second number; then use the "clear keyboard entry" key to clear and re-enter .0004 to see if you get the same answer

ASSIGNMENT SHEET #1

F. Use your "constant repeating key" $\boxed{K}$ to work the following:

(Round to 2 decimal places)

(1) 6.23 x 1.04 = _____

(2) 5.98 x 1.04 = _____

(3) 245.84 x 1.04 = _____

(4) 16.98 x 1.04 = _____

G. Obtain 22% of each of the following numbers (Use the $\boxed{\%}$ key)

(1) 268 = _____

(2) 139 = _____

(3) 44 = _____

6. Powers and roots

Use the $\boxed{\sqrt{x}}$ key and the $\boxed{x^2}$ key to solve: *Remember,* $x^2 = (x)(x)$; $y^x = (y)(y)(y)\ldots$ *x times.*

A. 2 = _____

B. $(16.9)^2 =$ _____

C. $(.0026)^2 \times (\sqrt{3}) \times 96{,}000 =$ _____

Use the y^x key to solve:

D. $2^3 =$ _____ (Enter $\boxed{2}\boxed{y^x}\boxed{3}\boxed{=}$ to obtain solution)

E. $\sqrt{3} =$ _____ (NOTE: The square root of a number equals $N^{1/2}$.)

F. $(.123)^{1.65} =$ _____

ASSIGNMENT SHEET #1

7. Logarithm Keys and Inverse Key

The natural logarithm system uses "e" as the base; that is 2.71828... and the common logarithm system uses "10" as the base.

The key for the common logarithm is $\boxed{\text{log}}$ and the key for the natural logarithm is $\boxed{\text{lnx}}$. Remember that the logarithm is the exponent that the base must be raised to in order to give a particular number.

Check to see that your calculator gives: log 10 = 1 and lnx 10 = 2.30258...

List 5 decimal places

A. log 100 = ____________ lnx 100 = ____________

B. log 36.85 = ____________ lnx 36.85 = ____________

Using your $\boxed{\text{INV}}$ key check the four answers in reverse; that is, press $\boxed{2}$ $\boxed{\text{INV}}$ $\boxed{\text{log}}$ to see if the display shows 100, etc.

8. Trigonometry keys (sin, cos, tan) and degree key

A. Sin 45° = ______ Cos 45° = ______ Tan 45° = ______

B. Sin 110° = ______ Cos 110° = ______ Tan 110° = ______

C. Sin $\pi/6$ (radians) = ______; Cos $\pi/6$ = ______; Tan $\pi/6$ = ______

(NOTE: Take your calculator out of the degree mode and place into the radian mode - also use the π key to obtain the value of pi. If your calculator functions only in degrees, calculate the number of degrees in $\pi/6$ radians. Pi radians equals 180 degrees.)

D. What angle has a sine of 0.5? (Use $\boxed{\text{INV}}$ key) ____________

(NOTE: This problem can be written arc sin 0.5, or $\sin^{-1}$ 0.5.)

9. My calculator has ____________ memory locations. Practice entering numbers into the various memory locations, recalling these numbers, exchanging numbers between memory and display, and summing numbers into memory (as appropriate).

SCIENTIFIC CALCULATIONS
UNIT III

ASSIGNMENT SHEET #2--SOLVE COMBINED MULTIPLICATION AND DIVISION PROBLEMS

Solve the following.

1. $\frac{160 \times 175}{28.5 \times 22} =$ ________

2. $\frac{156 \times 3.36}{75.5 \times 12.8} =$ ________

3. $\frac{160 \times 54 \times 0.0092}{92.8 \times 45 \times 0.986} =$ ________

4. $\frac{20}{375 \times 0.065 \times 980} =$ ________

5. $\frac{0.000655}{41 \times 80 \times 35} =$ ________

6. $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$

   What is R_T when $R_1 = 10$, $R_2 = 20$ and $R_3 = 30$?

   Answer________________________

7. $C_T = \frac{C_1 \times C_2}{C_1 + C_2}$

   What is C_T when $C_1 = .006$ and $C_2 = .010$?

   Answer________________________

8. Mark the correct solution to the problem following.

   _____a. 6 + 7 x 3 = 39

   _____b. 6 + 7 x 3 = 27

9. $(1.035)^2 - (.7)^3 + 6.5 \times 4 + (2)^{1.5} =$ ______________

SCIENTIFIC CALCULATIONS
UNIT III

ASSIGNMENT SHEET#3--CONVERT NUMBERS BETWEEN BINARY AND DECIMAL SYSTEMS.

(NOTE: A calculator is not used during this assignment

1. To convert a decimal number to a binary number:

   Divide the decimal number repeatedly by "2" and keep track of the remainders. The binary number will be the sequential listing of the remainders

   Example: Convert 6 to its proper binary number.

   $$\begin{array}{ll} 2\,\overline{)6} & 3\text{ R }0 \uparrow \\ & \underline{1\text{ R }1} \end{array}$$

   Thus, the binary number is 110

   Check: $110 = (1 \times 2^2) + (1 \times 2^1) + (0 \times 2^0) = 4 + 2 + 0 = 6$

   Convert the following from base 10 to base 2.

   A. 8 = ________ D. 3 = ________

   B. 15 = ________ E. 1 = ________

   C. 16 = ________ F. 25 = ________

2. Convert the following binary numbers to decimal numbers.

   A. $111_2 = \underline{\hspace{3cm}}_{10}$

   B. $1011_2 = \underline{\hspace{3cm}}_{10}$

   C. $111111_2 = \underline{\hspace{2cm}}_{10}$

   D. $100101_2 = \underline{\hspace{2cm}}_{10}$

SCIENTIFIC CALCULATIONS
UNIT III

ASSIGNMENT SHEET #4--EXPRESS NUMBERS IN SCIENTIFIC AND ENGINEERING NOTATION

Express the following numbers in both scientific and engineering notation (remember that engineering notation has exponents which are multiples of 3 - to conform to the standard prefixes used such as milli-, micro-, kilo-, mega-, etc.)

	Number	Scientific Notation	Engineering Notation
1.	96,000,000		
2.	0.00465		
3.	12.34		
4.	0.00000002167		
5.	34 milliamps		
6.	450 Megatons		
7.	15 microfarads		
8.	22.5 millihenrys		
9.	435.006		
10.	1645 Kilowatthours		

(NOTE: Suffixes used are equivalent to the following:

micro = 10^{-6}

milli = 10^{-3}

Kilo = 10^{3}

Mega = 10^{6}.)

SCIENTIFIC CALCULATIONS
UNIT III

ASSIGNMENT SHEET #5--OBTAIN TRIGONOMETRY FUNCTION VALUES

(NOTE: A ratio of two numbers measured in the same units results in a "unitless" number or a "pure fraction." For example, 3 inches divided by 4 inches equals 0.75. Not 0.75 inches but just the fraction 0.75. The three basic trigonometry functions (sin, cos, and tan) are ratios and have no units. However, these functions correspond to specific angles which can be measured in degrees, radians, or other units.)

If you have an electronic calculator with trigonometry functions, use it to obtain the following values, then check your numbers with a table of trigonometry functions. If you do not have a calculator, use the trigonometry tables. (Use 5 decimal places.)

	Angle	Sin	Cos	Tan
1.	45°			
2.	180°			
3.	90°			
4.	30°			
5.	60°			
7.	π radians			
8.	$\pi/6$ radians			
9.	89°30'			

(NOTE: π radians equals 180°. If your calculator does not have a "radian mode" of operation, first convert to degrees, then solve. When no units are given for the angle, it is assumed to be in radians.)

Example: $\sin 45^\circ = \sin \pi/4$

SCIENTIFIC CALCULATIONS
UNIT III

ASSIGNMENT SHEET #6-DETERMINE LOGARITHMS OF NUMBERS

(NOTE: Tables of logarithms (base 10) are only for numbers ranging from 1 to 10. If you use a table, you first write the number in scientific notation, use the exponent derived for "10" then look up the number between 1 and 10 in the table. If you are using an electronic calculator, the correct answer will be given by inserting the number and pressing "log" or "lnx.")

Determine the logarithms both for base 10 and base "e" of the following numbers: (Round off to nearest 5 decimal places)

	Number	Common Logarithm	Natural Logarithm (Base "e")
1.	100		
2.	22		
3.	13,000,000		
4.	0.000123		
5.	10		
6.	"e"		
7.	1		
8.	2		
9.	pi		

(NOTE: "e" equals 2.718281828... and "pi" equals 3.141592654...)

10. Notice that the values for the logarithm of the number "1" was the same for both bases. In general, if B is any positive number, the value of B^0 is equal to ____________.

11. Assume that $V = e^{(-t/RC)}$. What is the value of V when $t = 10$, $R = 1 \times 10^6$, and $C = 2 \times 10^{-6}$?

V = ________________

SCIENTIFIC CALCULATIONS
UNIT III

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

4. A. 447
   B. 569
   C. 656
   D. 1.01647

5. A. 30
   B. 15.5
   C. Can't divide by 0
   D. 4.468
   E. 0.0000013
   F. (1) 6.48
      (2) 6.22
      (3) 255.67
      (4) 17.66
   G. (1) 58.96
      (2) 30.58
      (3) 9.68

6. A. 1.4142
   B. 285.61
   C. 1.12403
   D. 8
   E. 1.7321
   F. 0.03150

7. A. 2, 4.60517
   B. 1.56644, 3.60686

8. A. .70711, .70711, 1
   B. 0.93969, -.34202, -2.74748
   C. 0.5, 0.86603, 0.57735
   D. 30

Assignment Sheet #2:

1. 44.7
2. 0.5423
3. 0.0193
4. 0.000837
5. 0.00000000571
6. 5.45
7. 0.00375
8. B
9. 29.56

Assignment Sheet #3

1. A. 1000
   B. 1111
   C. 10000
   D. 11
   E. 1
   F. 11001

2. A. 7
   B. 11
   C. 63
   D. 37

Assignment Sheet #4

1.	9.6×10^7	96×10^6
2.	4.65×10^{-3}	4.65×10^{-3}
3.	1.234×10^1	12.34×10^0 (or just 12.34)
4.	2.165×10^{-8}	21.67×10^{-9}
5.	3.4×10^{-2} amps	34×10^{-3} amps
6.	4.50×10^8 tons	450×10^6 tons
7.	1.5×10^{-5} farads	15×10^{-6} farads
8.	2.25×10^{-2} amps	22.5×10^{-3} amps
9.	4.35006×10^2	$435.006 \times 10^{\circ}$
10.	1.645×10^6 watthours	1.645×10^6 watthours

Assignment Sheet #5

	Angle	Sin	Cos	Tan
1.	45°	0.70711	0.70711	1.00000
2.	180°	0.00000	-1.00000	0.00000
3.	90°	1.00000	0.00000	+ infinity (indeterminate)
4.	30°	0.50000	0.86603	0.57735
5.	60°	0.86603	0.50000	1.73205
6.	15°	0.25882	0.96593	0.26795
7.	pi	0.00000	-1.00000	0.00000
8.	pi/6	0.50000	0.86603	0.57735
9.	89.5°	0.99996	0.00873	114.58865

Assignment Sheet #6:

	Number	Common Log.	Natural Log.
1.	100	2.00000	4.60517
2.	22	1.34242	3.09104
3.	13×10^6	7.11394	16.38046
4.	1.23×10^4	-3.91009	-9.00333
5.	10	1.00000	2.30259
6.	"e"	0.43429	1.00000
7.	1	0.00000	0.00000
8.	2	0.30103	0.69315
9.	"pi"	0.49715	1.14473
10.	1		
11.	0.00674		

SCIENTIFIC CALCULATIONS
UNIT III

NAME ______________________________

TEST

1. Match the terms on the right with the correct definitions.

_____a. Keys that enter, change, or erase numbers

_____b. Keys that perform mathematical operations, or that move data from one register to another

_____c. Locations in a calculator where numbers are placed for processing

_____d. The exponent to which a base is raised to give a particular number

_____e. One of a pair of numbers whose product is one

_____f. The expressing of numbers as the product of a number between 1 and 10, and an appropriate power of 10

_____g. Expressing numbers as the product of a number between 1 and 1000 and a power of 10 which is a multiple of 3

_____h. The digits in a number considered to be reliable

1. Register
2. Scientific notation
3. Data keys
4. Logarithm
5. Engineering notation
6. Function keys
7. Reciprocal
8. Significant digits

2. Match the data keys on the right with their functions on an electronic calculator.

_____a. Digit keys

_____b. Decimal point

_____c. Pi (3.14159...)

_____d. Change sign key

_____e. Clear or erase numbers in the display or in storage register

_____f. Enter exponent

1. π
2. EE or Exp or Eex
3. 0 through 9
4. C
5. .
6. +/-

3. Match the function keys on the right with their correct functions.

______a. Inverse key which reverses the purpose of the next key pressed

______b. Grouping to insure correct order of arithmetic operations

______c. Exchange value in display with value in memory

______d. Sum value in display into memory

______e. Recall from memory

______f. Store in memory

______g. The base y to the x power

______h. Constant key used for repetitive operations

______i. Places the calculator in the degree mode

______j. Calculate the tangent of number in display

______k. Calculate the cosine of number in display

______l. Calculate the sine of number in display

______m. Calculate common logarithm

______n. Calculate natural logarithm

______o. Calculate square root of number in display

______p. Square the number in display

______q. Calculate reciprocal of number in display

______r. Complete the arithmetic and display the answer

______s. Change percentage number to a decimal

______t. Divide by the next number

______u. Multiply by next number

______v. Subtract the next number

______w. Add the next number

1. x
2. =
3. $\sqrt{x}$
4. sin
5. Drg
6. STO
7. EXC
8. +
9. ÷
10. l/x
11. lnx
12. cos
13. K
14. RCL
15. ( )
16. -
17. %
18. x^2
19. log
20. tan
21. y^x
22. SUM
23. INV

4. Match the major categories of the number system on the right with the correct descriptions.

______a. Includes zero and positive integers

______b. A non-negative integer which is neither positive or negative

______c. The counting numbers or whole numbers of arithmetic

______d. Includes non-negative integers and negative integers

______e. Expressed in the form p/q where q is not equal to zero and q does not divide evenly into p.

______f. Includes integers and fractions

______g. Includes rational numbers and irrational numbers

______h. Numbers which cannot be expressed in the form p/q

______i. Includes real numbers and imaginary numbers

1. Real numbers
2. Fractions
3. Complex numbers
4. Zero
5. Non-negative integers
6. Irrational numbers
7. Positive integers
8. Rational numbers
9. Integer

5. Select true statements about the decimal and binary systems of numeration by placing an "X" in the appropriate blanks.

______a. In the decimal system of numeration, the base is 10

______b. Digits have place value in both the decimal and binary system of numeration

______c. There are nine digits (1, 2, 3, 4, 5, 6, 7, 8, and 9) in the decimal system of numeration

______d. Position placement of a digit is 10 times greater in one position than the position on its right in the decimal system

______e. In the binary system of numeration, the base is 1

______f. Position placement of a digit is two times greater than position on the right in the binary system

6. Express the following numbers in scientific notation.

   a. 136,000,000 = ____________________

   b. 0.000001204 = ____________________

7. State the laws of exponents when multiplying and dividing.

   a. Multiplication–____

   b. Division–____

8. Arrange in order the operations of computations by placing the correct sequence number in the appropriate blanks.

   _____ a. Multiply and divide in order from left to right

   _____ b. When parenthesis are present, perform the operations within the parenthesis

   _____ c. Add and subtract in order from left to right

   _____ d. Raise each base to power indicated

9. Match the trigonometry functions on the right with the statements which describe them on the left.

   _____ a. Values range from -1 to +1

   _____ b. In right triangle, is ratio of opposite side to adjacent side

   _____ c. In unit circle, is length of adjacent side

   _____ d. In this function, values can be any real number

   _____ e. In right triangle, is ratio of opposite side to hypotenuse

   _____ f. In right triangle, is ratio of adjacent side to hypotenuse

   _____ g. In unit circle, is length of tangent line to extended radius

   _____ h. In unit circle, is length of opposite side

   1. Sine function (sine θ)
   2. Cosine function (cos θ)
   3. Tangent function (tan θ)

10. Demonstrate the ability to:

    a. Use an electronic calculator.

    b. Solve combined multiplication and division problems.

    c. Convert numbers between binary and decimal systems.

    d. Express numbers in scientific and engineering notation.

    e. Obtain trigonometry function values.

    f. Determine logarithms of numbers.

    (NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

SCIENTIFIC CALCULATIONS
UNIT III

ANSWERS TO TEST

1. a. 3
b. 6
c. 1
d. 4
e. 7
f. 2
g. 5
h. 8

2. a. 3
b. 5
c. 1
d. 6
e. 4
f. 2

3. a. 23
b. 15
c. 7
d. 22
e. 14
f. 6
g. 21
h. 13
i. 5
j. 20
k. 12
l. 4
m. 19
n. 11
o. 3
p. 18
q. 10
r. 2
s. 17
t. 9
u. 1
v. 16
w. 8

4. a. 5
b. 4
c. 7
d. 9
e. 2
f. 8
g. 1
h. 6
i. 3

5. a, b, d, f

6. a. 1.36×10^8
b. 1.204×10^{-6}

7. a. $(B^m \times B^n) = B^{(m + n)}$

b. $\frac{B^m}{B^n} = B^{(m - n)}$

8. a. 3
b. 1
c. 4
d. 2

9. a. 1 and 2
b. 3
c. 2
d. 3
e. 1
f. 2
g. 3
h. 1

10. Evaluated to the satisfaction of the instructor.

RESISTANCE
UNIT IV

UNIT OBJECTIVE

After completion of this unit, the student should be able to select true statements about types of fixed resistors and the structure of adjustable resistors. The student should also be able to determine the resistance value from given color codes and measure circuit resistance with an ohmmeter. This knowledge will be evidenced by correctly performing the procedures outlined in the assignment and job sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms associated with electrical resistance with their correct definitions.
2. Select true statements about types of fixed resistors.
3. Distinguish between the two types of adjustable resistors.
4. Select true statements about the composition of fixed resistors.
5. Select true statements about the structure of adjustable resistors.
6. Select from a preferred resistance value chart resistors that are readily available.
7. Match resistor symbols and abbreviations with the terms that describe them.
8. State two methods of determining resistor values.
9. Discuss the color code four band system.
10. Discuss the color code five band system.
11. Complete a resistor color chart.
12. Compute the value of a resistor using the color chart.
13. List five parts of an ohmmeter.
14. Determine the resistance values from given color codes.
15. Demonstrate the ability to measure circuit resistance with an ohmmeter.

RESISTANCE
UNIT IV

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information, assignment, and job sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information and assignment sheets.

VI. Demonstrate and discuss procedures outlined in the job sheet.

VII. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:
  A. Objective sheet
  B. Information sheet
  C. Transparency masters
    1. TM 1--Resistance
    2. TM 2--Types of Resistors
    3. TM 3--Symbols Used For Resistance and Resistors
    4. TM 4--Resistor Color-Code Chart
    5. TM 5--Ohmmeter Scale and Range Settings
  D. Assignment Sheet #1--Determine Resistor Values From Given Color Codes
  E. Answers to assignment sheet
  F. Job Sheet #1--Measure Circuit Resistance With An Ohmmeter
  G. Test
  H. Answers to test

II. References:
  A. Grob, Bernard. *Basic Electronics.* New York: McGraw-Hill Book Co., 1977.

B. Marcus, Abraham, and Samuel E. Gendler. *Basic Electronics.* Englewood Cliffs, NJ: Prentice-Hall, Inc., 1971.

C. *Reference Data For Radio Engineers,* Fifth Edition, New York: Howard W. Sams & Co.

RESISTANCE
UNIT IV

INFORMATION SHEET

I. Terms and definitions

A. Resistance--Opposition which a device or material offers to the flow of electric current (Transparency 1)

(NOTE: All materials have resistance, but some materials have more than others.)

B. Resistor--A circuit component specifically designed to oppose the flow of electrical current

C. Ohm--The unit of measurement of resistance

(NOTE: One ohm is the value of resistance present when a potential difference of one volt causes a current of one ampere.)

D. Ohmmeter--An instrument used for measuring resistance

E. Wattage (power) rating--The maximum amount of electrical power (voltage and current) that can be applied to a resistor

F. Kilohm--One thousand (1,000 or 10^3) ohms

(NOTE: This word comes from the Greek "kilo" which means "thousand".)

G. Megohm--One million (1,000,000 or 10^6) ohms

(NOTE: This word comes from the Greek "mega" which means "million".)

H. Tolerance--The percentage above or below that a resistor's value can differ from its specified value

Example: A 100-ohm resistor with a tolerance of 10% should have an actual resistance value somewhere in the range of 90 to 110 ohms, that is, within 10% above or below the specified value

I. Fixed resistor--A resistor with a resistance value that cannot be varied

J. Adjustable resistor--A resistor with a resistance value that can be changed

(NOTE: Common methods of adjustment include a moveable tab, screwdriver adjustment, control knob, or similar device.)

INFORMATION SHEET

II. Types of fixed resistors (Transparency 2)

A. Carbon composition

1. Ratings--Made with wattage ratings of 1/8, 1/4, 1/2, 1, and 2 watts

   (NOTE: In general, the larger the physical size the higher the wattage.)

2. Values--Made in resistance values ranging from one ohm to twenty million ohms

3. Application--Made for use in low power applications

B. Wire wound

1. Ratings--Made with wattage ratings ranging from about three to several hundred watts

2. Values--Made in resistance values ranging from less than one ohm to several thousand ohms

3. Application--Made for use mainly in low resistance, high power applications

C. Film and ceramic

1. Ratings--Made with wattage ratings ranging from 1/20 to two watts

2. Values--Made in resistance values ranging from less than one ohm to several thousand ohms

3. Application--Made for use in low power applications

III. Types of adjustable resistors (Transparency 2)

A. Variable (tapped)

1. Values--Made with adjustable resistance values ranging from zero to the maximum of the component

2. Application--Made for use as voltage dividers

B. Rheostat/Potentiometer

1. Values--Made with adjustable resistance values ranging from zero to the maximum of the component

2. Application--Made for use as dimmer controls and in electronic adjustment applications

INFORMATION SHEET

IV. Composition of fixed resistors

A. Composition resistors are made of powdered carbon or graphite mixed with insulating material

B. Wire wound resistors are made by winding resistance wire around an insulating core

C. Film and ceramic resistors are made by depositing a thin film of resistive material on an insulating core

V. Structure of adjustable resistors (Transparency 2)

A. Variable resistors (tapped) are made with two or more fixed terminals and a movable terminal

B. Potentiometers are made with two fixed terminals and one adjustable terminal with a movable wiper

(NOTE: Movement is accomplished with knob and shaft, screwdriver, or movable tab.)

C. Rheostats are made with one fixed and one movable terminal

VI. Preferred resistance values

A. The chart in Figure 1 shows preferred resistance values for resistors with tolerances of ± 20%, ± 10%, and ± 5%

B. The chart in Figure 1 is based on USA Standard C83.2

C. "Preferred values" means that the U.S. Government recommends that manufacturers make and supply resistors in these values to stores

D. Reasons for preferred values

1. Helps limit the numbers of parts that need to be manufactured and stocked

INFORMATION SHEET

2. Helps insure availability of interchangeable resistors

PREFERRED RESISTANCE VALUES

20%	10%	5%
10	10	10
--	--	11
--	12	12
--	--	13
15	15	15
--	--	16
--	18	18
22	22	22
--	--	24
--	27	27
--	--	30
33	33	33
--	--	36
--	39	39
--	--	43
47	47	47
--	--	51
--	56	56
--	--	62
68	68	68
--	--	75
--	82	82
--	--	91
100	100	100

FIGURE 1

E. To find resistance values larger or smaller than the numbers given in the table, multiply the given number by the proper multiple of ten (.01, .1, 10, 100, 1000, etc.)

Example: The 30 in the chart under the ± 5% column means that resistors with ± 5% tolerance can be purchased in decimal multiples such as .3, 3, 30, 300, 3,000, or 30,000

F. Dashes in the +10% and ± 20% columns indicate resistance values that are not available in these tolerances

Example: Resistors in the 24-ohm series (.24, 2.4, 24, 240, 2400, 24000, etc. ohms) are available only with a tolerance of ± 5%

VII. Symbols used for resistance and resistors (Transparency 3)

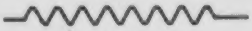
A. Ohm-- Ω

(NOTE: Ω is the Greek capital letter "omega".)

INFORMATION SHEET

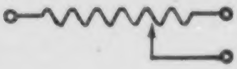
B. Kilohm (1000 ohms)--K or K Ω

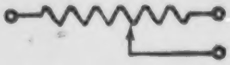
C. Megohm (1,000,000 ohms)--M or M Ω

D. Resistor schematic symbol-- 

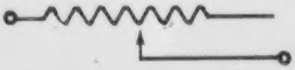
E. Resistor letter symbol--R

F. First, second, third, etc., resistors, in a circuit--R1, R2, R3, etc.

G. Adjustable (tapped wire) resistor-- 

H. Potentiometer-- 

(NOTE: Variable resistors and potentiometers both have three terminals with one movable so their schematics are the same; however, a rheostat has only two terminals with one movable so the schematic symbol is different.)

I. Rheostat-- 

VIII. Methods of determining resistor values

A. Large wattage resistors have their value stamped on the resistor

Example: 47 Ω, 47 K Ω, 47 M Ω

B. Small wattage resistor values are determined by color bands

IX. The color code four band system (Transparency 4)

A. First band--First digit of value

B. Second band--Second digit of value

C. Third band--Multiplier (power of ten)

D. Fourth band--Tolerance

X. The color code five band system (Transparency 4)

A. First band--First digit of value

B. Second band--Second digit of value

C. Third band--Multiplier (power of ten)

D. Fourth band--Tolerance

INFORMATION SHEET

E. Fifth band--Percent of failure per 1000 hours during reliability tests

(NOTE: The five band system is used mostly in military applications.)

XI. The resistor color chart

Memory Starter	Color	Value
Bad	Black	0
Boys	Brown	1
Race	Red	2
Our	Orange	3
Young	Yellow	4
Girls	Green	5
But	Blue	6
Violet	Violet	7
Generally	Gray	8
Wins	White	9

XII. Determining resistor values with the color chart

A. Always read left to right starting with the band closest to the end

Example: If the first color on the left is yellow, the first number is 4

B. Place the value of the second color next to the first value

Example: If the second color is violet, the value is 7, so combined with 4, the first two values become 47

C. Add zeros to indicate the value of the third color which is the decimal multiplier

Example: If the third color is orange, the value is 3, so add 47, three zeros and the value then becomes 47,000

D. When gold or silver are used as a third band, they too become decimal multipliers; gold is a multiplier of 0.1, silver is a multiplier of .01

E. Gold or silver used as a fourth band indicates the accuracy of the resistance value; gold means 5% accuracy (tolerance) and silver means 10% accuracy (tolerance)

Example: Yellow-violet-orange-gold = 47,000 ± 5% ohms
Yellow-violet-black-gold = 47 ± 5% ohms
Yellow-violet-gold-silver = 4.7 ± 10% ohms

INFORMATION SHEET

XIII. Parts of an ohmmeter (Transparency 5)

A. Indicator

B. Scale

C. Range selector switch

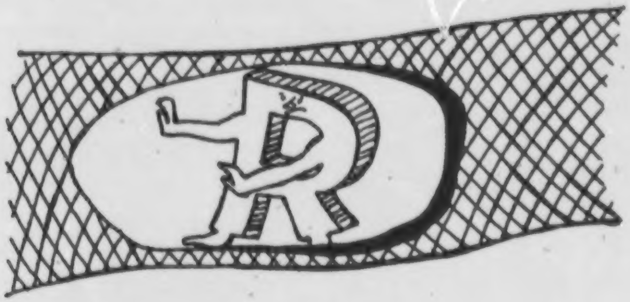
(NOTE: On the range selector switch of a typical ohmmeter, three selections may be made: R x 1 (multiply indication by 1), R x 1000 (multiply indication by 1000), and R x 10,000 (multiply indication by 10,000).)

D. Connecting leads

E. Ohms adjust or zero adjust control

(NOTE: Many ohmmeters are combined with voltmeters and ammeters in one instrument called a multimeter. This instrument has many scales used for reading resistance, voltage or current, and a selector switch for selecting the proper function.)

Resistance



Resistance is opposition to current flow

Definition: Resistance can be said to be the internal friction involved in the passing of electrons through a wire.

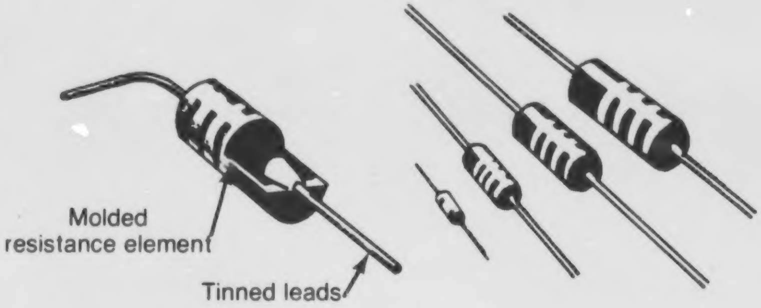
Symbol: R

Measured in: Ohms

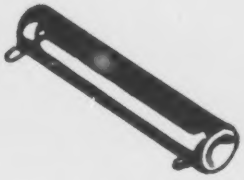
Instrument used to measure: Ohmmeter

Types Of Resistors

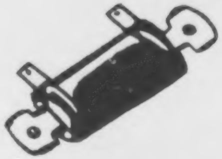
FIXED


Molded resistance element
Tinned leads

Carbon-Composition Resistors

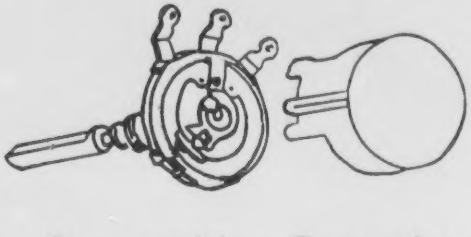


Wire-Wound Resistor

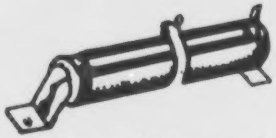


Film-Element Resistor

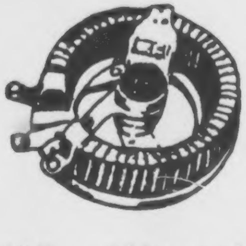
ADJUSTABLE



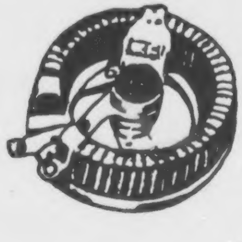
Carbon-Composition Potentiometer



Wire-Wound
Variable Resistor

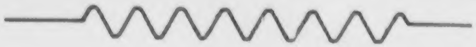
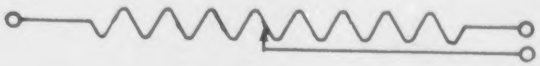
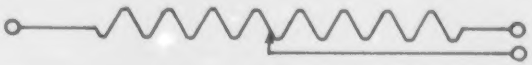
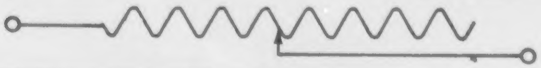


Wire-Wound
Potentiometer



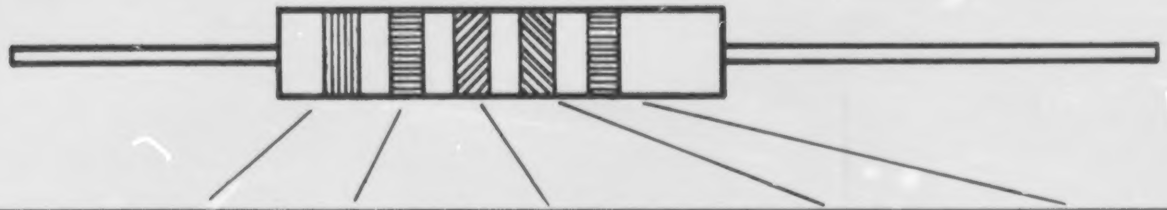
Wire-Wound Rheostat

Symbols Used For Resistance And Resistors

ITEM	LETTER SYMBOL	GRAPHIC (SCHEMATIC) SYMBOL
OHM	(GREEK CAPITAL LETTER "OMEGA") Ω	
KILOHM	K or K Ω	
MEGOHM	M or M Ω	
RESISTOR	R	
FIRST, SECOND, THIRD, ETC. RESISTOR	R 1, R 2, R 3, etc.	
VARIABLE (TAPPED WIRE) RESISTOR	R	
POTENTIOMETER	R	
RHEOSTAT	R	

BE - 149-C

Resistor Color-Code Chart



Color	Band 1	Band 2	Band 3	Band 4	Band 5*
	1st Digit (Number)	2nd Digit (Number)	Multiplier	Tolerance (per cent)	Reliability (per cent)
Black	0	0	10^0 1		
Brown	1	1	10^1 10	1	1.0
Red	2	2	10^2 100	2	0.1
Orange	3	3	10^3 1,000	3	0.01
Yellow	4	4	10^4 10,000	4	0.001
Green	5	5	10^5 100,000		
Blue	6	6	10^6 1,000,000		
Violet	7	7	10^7 10,000,000		
Gray	8	8	10^8 100,000,000		
White	9	9	10^9 1,000,000,000		
Gold			10^{-1} 0.1	5	
Silver			10^{-2} 0.01	10	
none				20	Not tested

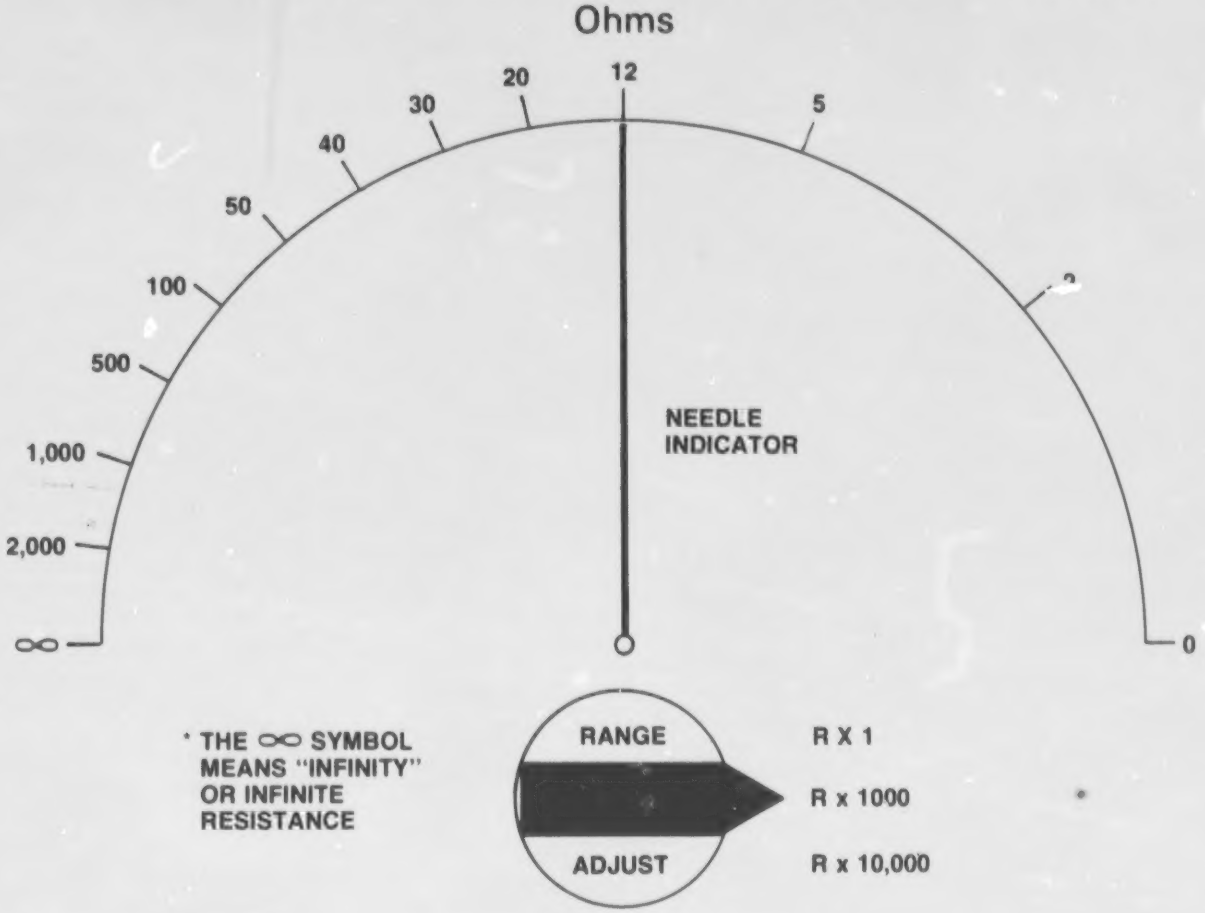
Mnemonic (a way to remember) for the Color Code

* Band 5 applies to resistors made for military use.

BAD BOYS RACE OUR YOUNG GIRLS BUT VIOLET GENERALLY WINS

0 1 2 3 4 5 6 7 8 9

Ohmmeter Scale and Range Settings


Ohms
12
20
30
40
50
100
500
1,000
2,000
∞
5
2
0
NEEDLE INDICATOR
RANGE
ADJUST
R X 1
R x 1000
R x 10,000

* THE ∞ SYMBOL MEANS "INFINITY" OR INFINITE RESISTANCE

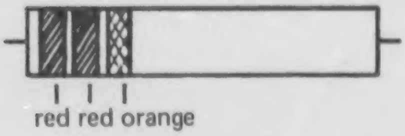
WITH RANGE ADJUST SET ON	METER INDICATION IS
R x 1	12 x 1 or 12 Ohms
R x 100	12 x 1,000 or 12,000 Ohms
R x 10,000	12 x 10,000 or 120,000 Ohms

RESISTANCE
UNIT IV

ASSIGNMENT SHEET #1--DETERMINE THE RESISTANCE VALUES FROM GIVEN COLOR CODES

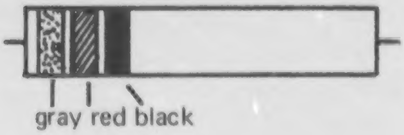
1. Compute the value of the following resistors

a.


red red orange

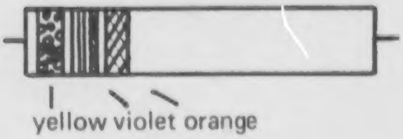
= __________ ohms or __________ K

b.


gray red black

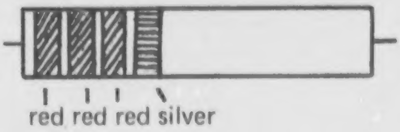
= __________ ohms

c.


yellow violet orange

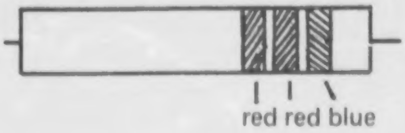
= __________ ohms or __________ K

d.


red red red silver

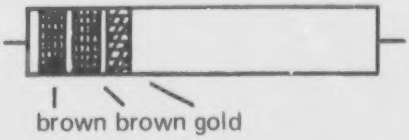
= __________ ohms or __________ K

e.


red red blue

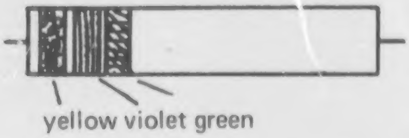
= __________ ohms or __________ K

f.


brown brown gold

= __________ ohms

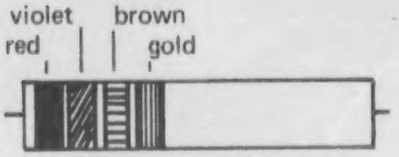
g.


yellow violet green

= __________ ohms or __________ K
or __________ M

ASSIGNMENT SHEET #1

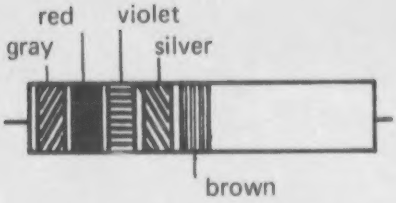
h.


violet
brown
red
gold

= ____________ ohms

tolerance ± ____________ %

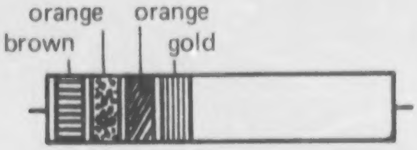
i.


red
violet
gray
silver
brown

= ____________ ohms or ____________ M

tolerance ± ____________ %

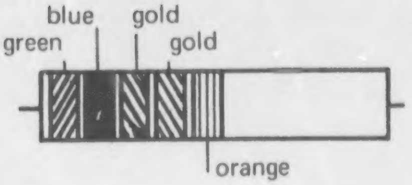
j.


orange
orange
brown
gold

= ____________ ohms or ____________ K

tolerance ± ____________ %

k.


blue
gold
green
gold
orange

= ____________ ohms

tolerance ± ____________ %

2. The minimum value you would expect resistor "d" to have is ____________ ohms and the maximum value you would expect is ____________ ohms (assuming that it is within tolerance)

3. Refer to the resistors above and answer the following questions.

   a. If the circuit voltage is constant, which resistor would pass the greatest current?

      ____

   b. If the circuit voltage is constant, which resistor would pass the least current?

      ____

   c. What is the largest value resistor "g" can have and still be within tolerance?

      ____

4. The fifth color band in resistors "i" and "k" above represents resistor ____________

RESISTANCE
UNIT IV

ANSWERS TO ASSIGNMENT SHEET

Assignment Sheet #1

1. a. 22,000 ohms or 22 K Ω
   b. 82 ohms
   c. 47,000 ohms or 47 K Ω
   d. 2200 ohms or 2.2 K Ω
   e. 6200 ohms or 6.2 K Ω
   f. 1.1 ohms
   g. 4,700,000 ohms or 4700 K Ω or 4.7 M Ω
   h. 270 ohms, tolerance ± 5%
   i. 82,000,000 ohms or 82 K Ω tolerance ± 10%
   j. 13,000 ohms or 13 K Ω , tolerance ± 5%
   k. 5.6 ohms, tolerance 5%
2. 1980 ohms minimum (2200 - 220) ohms maximum (2200 ± 10%)
3. a. f
   b. g
   c. 5.64 megohms (4.7 megohms ± 20% = 4.7 + .94 = 5.64 megohms)
4. Reliability

RESISTANCE
UNIT IV

JOB SHEET #1--MEASURE CIRCUIT RESISTANCE WITH AN OHMMETER

I. Tools and materials

   A. Ohmmeter or multimeter with ohmmeter capability

   B. Five assorted resistors with color code markings

   C. One lamp or light bulb

II. Procedure

   A. Read and record the value of each resistor as indicated by the color code markings

   B. Connect the ohmmeter to each resistor and record the measured value beside the color-coded value

   C. Write "IN" if the measured value is within the tolerance indicated by the color code markings and write "OUT" if this is not true

   D. Measure and record the resistance of the lamp

   (NOTE: Discuss any difficulty with this measurement with your instructor.)

   E. Return tools and materials to proper storage area

RESISTANCE
UNIT IV

NAME ______________________________

TEST

1. Match the terms on the right with the correct definitions.

_____a. The percentage above or below that a resistor's value can differ from its specified value

_____b. The unit of measurement of resistance

_____c. A resistor with a resistance value that can be changed

_____d. A circuit component specifically designed to oppose the flow of electrical current

_____e. Opposition which a device or material offers to the flow of electrical current

_____f. One thousand ohms

_____g. A resistor with a resistance value that cannot be varied

_____h. One million ohms

_____i. The maximum amount of electrical power that can be applied to a resistor

_____j. An instrument used for measuring resistance

1. Resistance
2. Resistor
3. Ohm
4. Ohmmeter
5. Wattage rating
6. Kilohm
7. Megohm
8. Tolerance
9. Fixed resistor
10. Adjustable resistor

2. Select true statements about types of fixed resistors by placing an "X" in the appropriate blanks.

_____a. Carbon composition resistors are made with wattage ratings of 1/8, 1/4, 1/2, 1, and 2 watts

_____b. Carbon composition resistors are made in resistance values ranging from one ohm to twenty million ohms

_____c. Carbon composition resistors are made for use in electronic adjustment applications

_____d. Wire wound resistors are made with wattage ratings ranging from three hundred to several thousand watts ______e. Wire wound resistors are made in resistance values ranging from less than one ohm to several thousand ohms

______f. Wire wound resistors are made for use mainly in low resistance, high power applications

______g. Film and ceramic resistors are made with wattage ratings ranging from 1/20 to two watts

______h. Film and ceramic resistors are made in resistance values ranging from less than one ohm to several thousand ohms

______i. Film and ceramic resistors are made for use in medium power applications

3. Distinguish between variable and rheostat adjustable resistors by placing a "V" next to descriptions of variable adjustable resistors.

______a. Made for use as voltage dividers

______b. Made with adjustable resistance values ranging from zero to the maximum of the component

______c. Made for use as dimmer controls and in electronic adjustment applications

4. Select true statements about the composition of fixed resistors by placing an "X" in the appropriate blanks.

______a. Composition resistors are made of powdered carbon or graphite mixed with insulating material

______b. Wire wound resistors are made by winding resistance wire around an insulating core

______c. Film and ceramic resistors are made by depositing a thin film of resistive material on an insulating core

5. Select true statements about the structure of adjustable resistors by placing an "X" in the appropriate blanks.

______a. Variable resistors are made with two or more fixed terminals and movable end terminals

______b. Potentiometers are made with two fixed terminals and one adjustable terminal with a movable wiper

______c. Rheostats are made with one fixed and two movable terminals

6. Select from the preferred resistance value chart which of the listed resistors are readily available by placing an "X" in the appropriate blanks.

_____a. 10 Ω, ± 5%

_____b. 680 Ω, ± 10%

_____c. 36 K Ω, ± 20%

_____d. 27 M Ω, ± 5%

_____e. 310 Ω, ± 5%

_____f. 4.3 K Ω, ± 10%

_____g. 15 M Ω, ± 20%

_____h. 100 K Ω, ± 5%

_____i. 70 Ω, ± 10%

_____j. 120 K Ω, ± 10%

_____k. 430 Ω, ± 20%

_____l. 22 M Ω, ± 10%

_____m. 330 Ω, ± 20%

_____n. 830 K Ω, ± 5%

_____o. 4.7 M Ω, ± 10%

PREFERRED RESISTANCE VALUES

±20%	±10%	±5%
10	10	10
..	..	11
..	12	12
..	..	13
15	15	15
..	..	16
..	18	18
22	22	22
..	..	24
..	27	27
..	..	30
33	33	33
..	..	36
..	39	39
..	..	43
47	47	47
..	..	51
..	56	56
..	..	62
68	68	68
..	..	75
..	82	82
..	..	91
100	100	100

7. Match resistor symbols and abbreviations with the terms on the left that correctly describe them.

_____a. Ohm

_____b. Kilohm

_____c. 1,000,000 ohms

_____d. Resistor schematic symbol

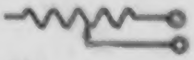
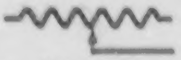
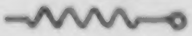
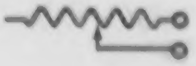
_____e. Resistor letter symbol

_____f. First resistor in a circuit

_____g. Potentiometer

_____h. Rheostat

_____i. Variable resistor

1. 
2. R1
3. M or M Ω
4. R
5. Ω
6. 
7. 
8. K or K Ω
9. 

8. State the two methods of determining resistor values.

a. ____

b. ____

9. Discuss the color code four band system.

10. Discuss the color code five band system.

11. Complete a resistor color chart by correctly filling in the colors and values suggested by the memory starters.

Memory Starter	Color	Value
Bad	a.	b.
Boys	c.	d.
Race	e.	f.
Our	g.	h.
Young	i.	j.
Girls	k.	l.
But	m.	n.
Violet	o.	p.
Generally	q.	r.
Wins	s.	t.

12. Compute the value of the following resistor using values from the resistor color chart:

Yellow-violet-black-gold = ____________________

13. List five parts of an ohmmeter.

a. ____

b. ____

c. ____

d. ____

e. ____

14. Determine the resistance value from given color codes.

15. Demonstrate the ability to measure resistance using an ohmmeter.

(NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

RESISTANCE
UNIT IV

ANSWERS TO TEST

1. a. 8
   b. 3
   c. 10
   d. 2
   e. 1
   f. 6
   g. 9
   h. 7
   i. 5
   j. 4

2. a, b, e, f, g, h

3. a, b

4. a, b, c

5. b

6. a, b, d, g, h, j, l, m, o

7. a. 5
   b. 8
   c. 3
   d. 7
   e. 4
   f. 2
   g. 1 or 9
   h. 6
   i. 9 or 1

8. a. Large wattage resistors have their value stamped on the resistor
   b. Small resistor values are determined by color bands

9. Discussion should include:
   a. First band--First digit of value
   b. Second band--Second digit of value
   c. Third band--Multiplier
   d. Fourth band--Tolerance

10. Discussion should include:
    a. First band--First digit of value
    b. Second band--Second digit of value
    c. Third band--Multiplier
    d. Fourth band--Tolerance
    e. Fifth band--Percent of failure per 1000 hours during reliability tests

11. a. Black
    b. 0
    c. Brown
    d. 1
    e. Red
    f. 2
    g. Orange
    h. 3
    i. Yellow
    j. 4
    k. Green
    l. 5
    m. Blue
    n. 6
    o. Violet
    p. 7
    q. Gray
    r. 8
    s. White
    t. 9

12. 47 ±5% ohms

13. a. Indicator
    b. Scale
    c. Range selector switch
    d. Connecting leads
    e. Ohms adjust or zero adjust control

14. Evaluated to the satisfaction of the instructor

15. Performance skills evaluated to the satisfaction of the instructor

VOLTAGE AND MEASUREMENT
UNIT V

UNIT OBJECTIVE

After completion of this unit, the student should be able to demonstrate the ability to measure and compare the voltage of different batteries and measure the voltage drops in a DC circuit. This knowledge will be evidenced by correctly performing the procedures outlined on the assignment and job sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms associated with voltage and measurement with their definitions.
2. Name three common sources of voltage.
3. Match symbols and abbreviations related to voltage and measurement with their definitions.
4. Select principal parts of a typical voltmeter.
5. Arrange in order the procedures for using a voltmeter.
6. State Kirchhoff's law of voltage.
7. Discuss current flow in a resistive circuit.
8. Discuss polarity in a resistive circuit.
9. State the formulas for voltage drops in resistive circuits.
10. Read voltmeter scales.
11. Demonstrate the ability to:
    a. Measure and compare the voltage of three different batteries.
    b. Measure the voltage drops in a DC circuit.

VOLTAGE AND MEASUREMENT
UNIT V

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information, assignment, and job sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information and assignment sheets.

VI. Demonstrate and discuss the procedures outlined in the job sheets.

VII. Demonstrate the use of voltmeters, probes, and auxiliary equipment.

VIII. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:
  A. Objective sheet
  B. Information sheet
  C. Transparency masters
    1. TM 1--Voltage
    2. TM 2--Using a DC Voltmeter to Measure Voltage Drop
    3. TM 3--Voltmeter Scales and Range Settings
    4. TM 4--Kirchhoff's Law of Voltage
    5. TM 5--Voltage Drops in a Resistive Circuit
  D. Assignment Sheet #1--Read Voltmeter Scales
  E. Answers to assignment sheet
  F. Job sheets
    1. Job Sheet #1--Measure and Compare the Voltage of Three Different Batteries
    2. Job Sheet #2--Measure the Voltage Drop in a DC Circuit

G. Test

H. Answers to test

II. References:

A. Grob, Bernard. *Basic Electronics,* Fifth Edition. New York: McGraw-Hill, 1977.

B. Marcus, Abraham, and Samuel E. Gendler. *Basic Electronics,* Second Edition. Englewood Cliffs, NJ: Prentice-Hall, 1971.

VOLTAGE AND MEASUREMENT
UNIT V

INFORMATION SHEET

I. Terms and definitions

  A. Voltage--Electrical force or pressure that causes the flow of electrical current (electrons)

  B. Volt--The unit of measurement of electromotive force (Transparency 1)

  (NOTE: One volt forces one ampere of current through one ohm of resistance.)

  C. Voltage drop--Difference in voltage measured across a component in a circuit (Transparency 2)

  D. Voltmeter--Instrument used to measure voltage

II. Common voltage sources

  A. Batteries

  B. Generators/alternators

  C. Electronic power supplies

III. Voltage symbols or abbreviations and definitions

  A. EMF or emf--Electromotive force

  (NOTE: EMF is the same as voltage.)

  B. E or e--Voltage source or applied voltage

  C. V or v--Voltage or voltage drop

  D. KV or kv--Kilovolt (one thousand volts)

  E. MV--Megavolt (one million volts)

  F. mV--Millivolt (one-thousandth of a volt)

  G. μV--Microvolt (one-millionth of a volt)

  H. VM--Voltmeter

INFORMATION SHEET

IV. Principal parts of a voltmeter (multimeter)

- A. Connecting leads or probes
- B. Function switches
  - 1. Voltage, current, resistance
  - 2. Direct current, alternating current
- C. Multiple use scales (Transparencies 3 and 4)
- D. Range switch (to select proper range)

  (NOTE: A range position should be selected, when possible, for the middle-third region of a scale where the meter is most accurate.)

V. Procedures for using a voltmeter

- A. Hold probes by insulated part
- B. Assure that meter will read expected voltage
- C. Set range switch for correct range
- D. Use correct polarity of probes
  - 1. Negative or common probe toward negative of power supply
  - 2. Positive probe toward positive of power supply
- E. Connect voltmeter in parallel with load
- F. Read voltage on meter
- G. Remove probes

VI. Kirchhoff's law of voltage--The algebraic sum of the voltage drops around a closed loop must equal the applied voltage (Transparency 5)

VII. Current flow in a resistive circuit

- A. Negative to positive
- B. Resultant potential across resistance (voltage drop)

VIII. Polarity in a resistive circuit

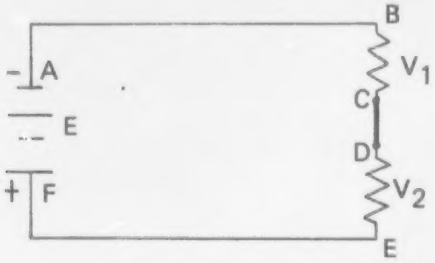
- A. End nearer negative of supply is negative
- B. End nearer positive of supply is positive

INFORMATION SHEET

IX. Formulas for voltage drops in resistive circuits (Transparency 6)

A. Voltages in circuit equal power source: $V_1 + V_2 = E$

B. Algebraic sum of voltage drops equal zero: $V_1 + V_2 - E = 0$ (Figure 1)



Example: Point A is most negative point in circuit

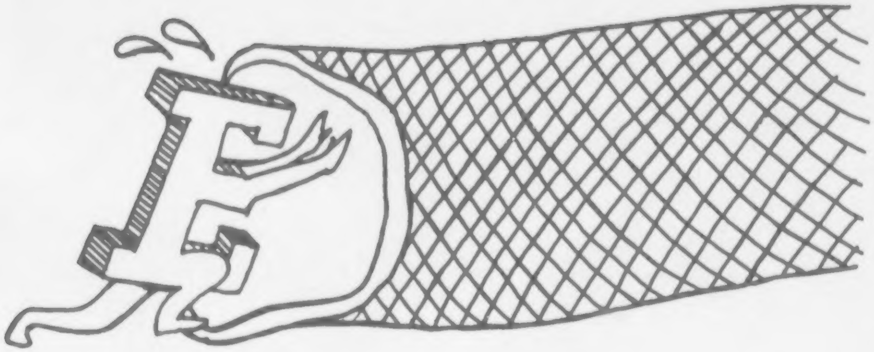
Point F is most positive point in circuit

Point B is negative with respect to Point C

Point D (same as Point C) is negative with respect to Point F

Expressed in formula: $V_1 + V_2 = E$ or $V_1 + V_2 - E = 0$

Voltage



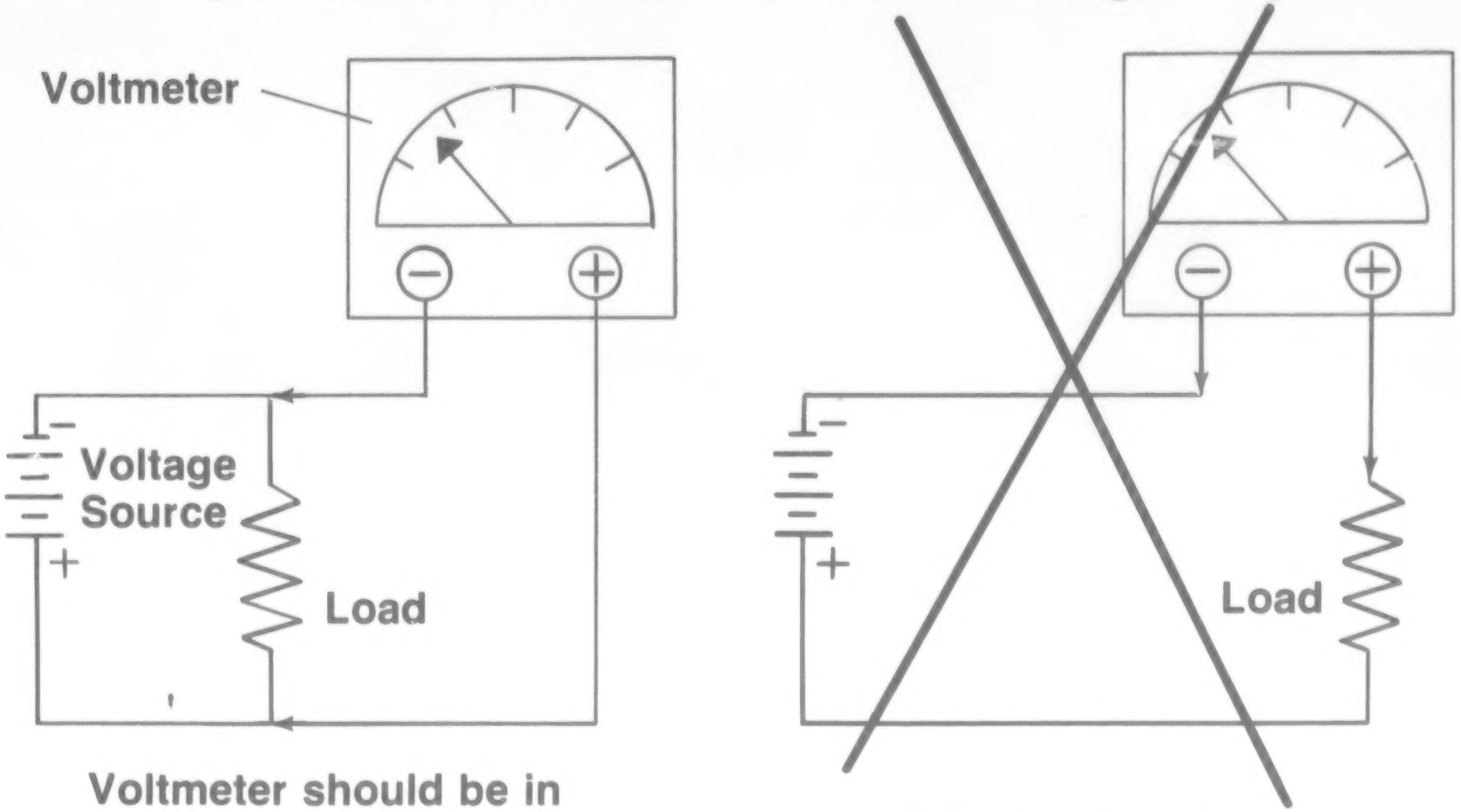
Voltage is pressure, or electromotive force

Voltage makes electrons "want to move" — Symbol: E or V

Measured in: Volts — Symbol: V

Instrument used to measure: Voltmeter. Symbol -Ⓥ-

Using a DC Voltmeter to Measure Voltage Drop


Voltmeter
Voltage Source
Load
Load

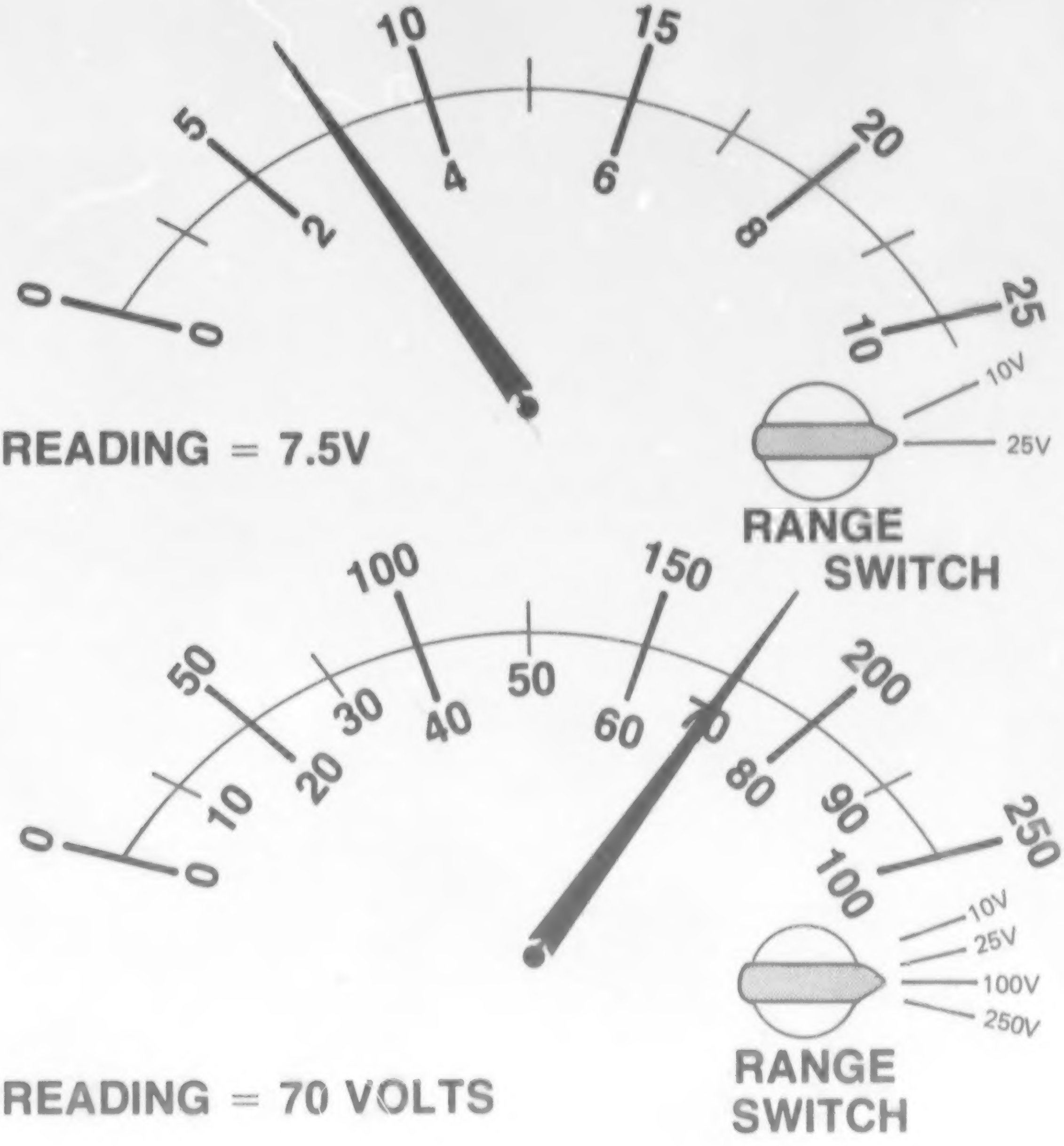
Voltmeter should be in parallel with load

NEVER in Series

TM 2

BE - 177-C

VOLTMETER SCALES AND RANGE SETTINGS


0
5
10
15
20
25
0
2
4
6
8
10
10V
25V
RANGE SWITCH
0
50
100
150
200
250
0
10
20
30
40
50
60
70
80
90
100
10V
25V
100V
250V
RANGE SWITCH

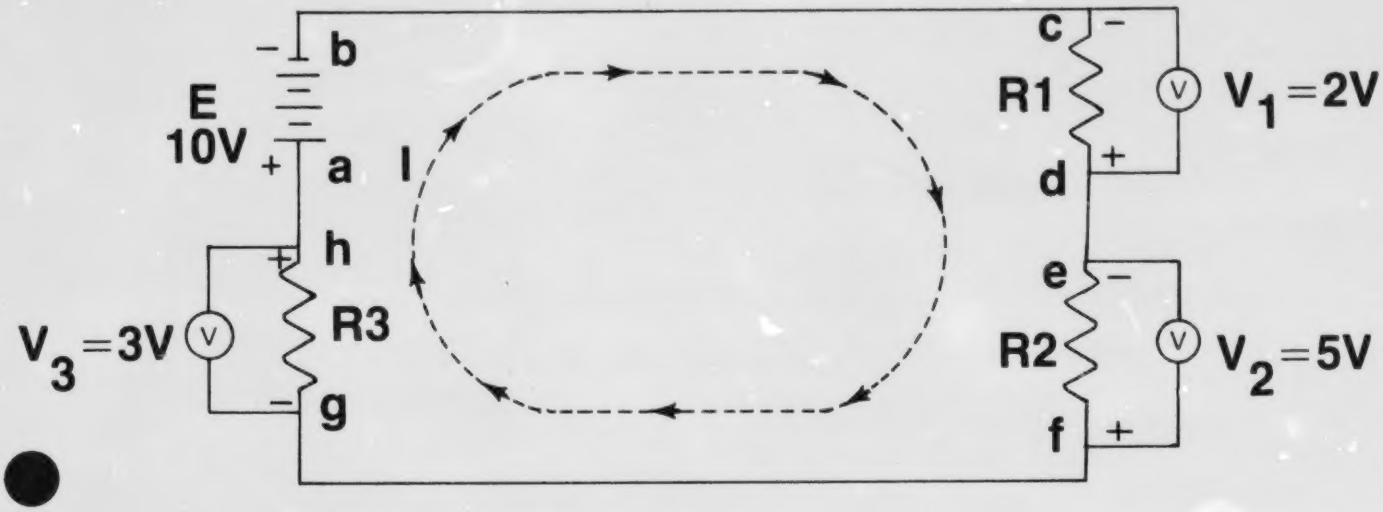
READING = 7.5V

READING = 70 VOLTS

Kirchhoff's Law of Voltage

The algebraic sum of the voltages around a closed loop must equal the applied voltage.

Voltage Drops in a Resistive Circuit


b
E
10V
a
I
h
R3
$V_3=3V$
g
c
R1
$V_1=2V$
d
e
R2
$V_2=5V$
f

Applied Voltage (E) = 10V

Direction of Electron Flow: Negative (b) to Positive (a)

Application of Kirchhoff's Law of Voltage:

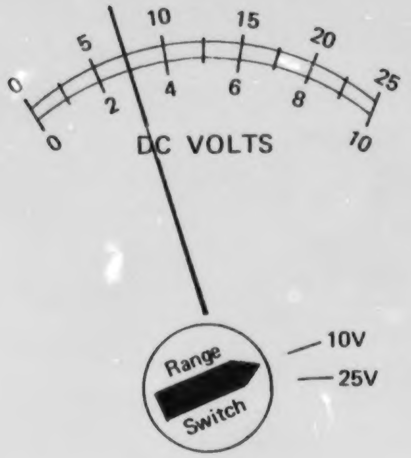
$$V_1 + V_2 + V_3 - E1$$

$$2V + 5V + 3V = 10V$$

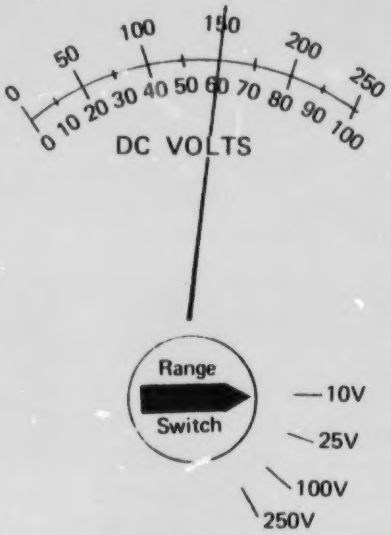
VOLTAGE AND MEASUREMENT
UNIT V

ASSIGNMENT SHEET #1–READ VOLTMETER SCALES

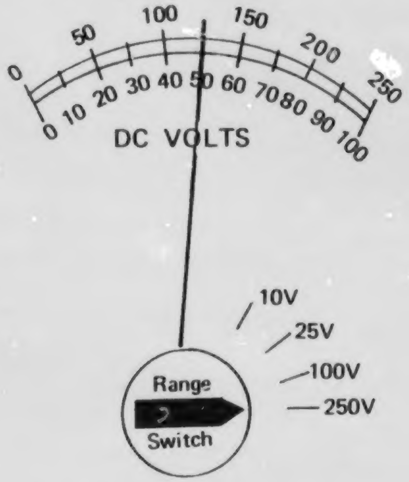
Directions: Write down the voltage reading indicated by the scales.


0
5
10
15
20
25
0
2
4
6
8
10
DC VOLTS
Range Switch
10V
25V

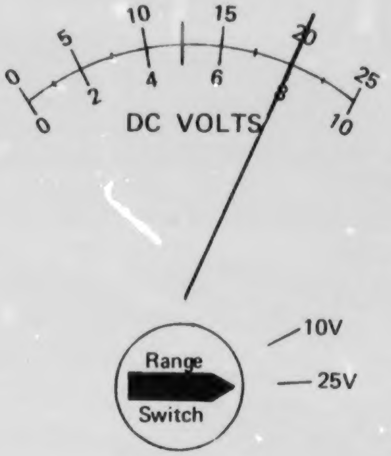
a. ______________________


0
50
100
150
200
250
0 10 20 30 40 50 60 70 80 90 100
DC VOLTS
Range Switch
10V
25V
100V
250V

b. ______________________


0
50
100
150
200
250
0 10 20 30 40 50 60 70 80 90 100
DC VOLTS
10V
25V
100V
250V
Range Switch

c. ______________________


0
5
10
15
20
25
0
2
4
6
8
10
DC VOLTS
Range Switch
10V
25V

d. ______________________

VOLTAGE AND MEASUREMENT
UNIT V

ANSWERS TO ASSIGNMENT SHEET #1

a. 3v

b. 6v

c. 125v

d. 20v

VOLTAGE AND MEASUREMENT
UNIT V

JOB SHEET #1--MEASURE AND COMPARE THE VOLTAGE OF THREE DIFFERENT BATTERIES

I. Tools and equipment

   A. Multimeter or voltmeter with leads

   B. Three batteries with different voltages

II. Procedure

   A. Check to see that the meter is a DC meter, or if it is a multimeter, make sure it is set to DC

   B. Place the test leads in their proper connectors in the meter

   (NOTE: The negative lead goes to the "-" connector and the positive lead goes to the "+" connector.)

   C. Set the full-scale reading on the voltmeter higher than the expected voltage

   D. Hold the test leads by the insulated part

   (CAUTION: Touching the metal part could make you part of the circuit and result in a shock.)

   E. Connect the negative lead to the negative terminal of a battery, then connect the positive lead to the positive terminal of the battery

   F. Read and record the voltmeter indication

   G. Disconnect one of the meter leads, and after the voltmeter goes to zero, reconnect the lead

   H. Read and record the voltmeter indication again

   I. Repeat steps F, G, and H a third time

   J. Repeat steps F, G, and H for each of the other two batteries until you record a total of nine voltmeter readings

   (NOTE: Discuss the following in class:

   1. The importance of connecting the positive lead to the positive terminal and the negative lead to the negative terminal

   2. How to obtain an accurate voltmeter reading if the meter pointer does not fall exactly on a scale mark

JOB SHEET #1

3. Compare the advantages and disadvantages of multimeters with single purpose meters

4. How the range of a voltmeter is determined

5. The differences of the three readings taken on a battery.)

K. Return meters and batteries to proper storage area

VOLTAGE AND MEASUREMENT
UNIT V

JOB SHEET #2--MEASURE THE VOLTAGE DROP IN A DC CIRCUIT

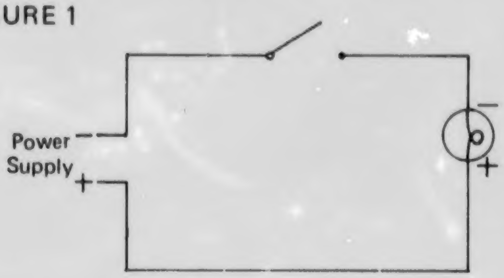
I. Tools and equipment

- A. Voltmeter
- B. Power supply
- C. Lamp or load
- D. Switch

II. Procedure

- A. Connect the power supply to the lamp or load as shown in Figure 1

FIGURE 1



- B. Close the switch
- C. Connect the voltmeter across the power supply and adjust for 1 1/2 volts
- D. Read and record the voltmeter indication
- E. Connect the voltmeter across the lamp or load
- F. Read and record the voltmeter indication
- G. Connect the voltmeter to the "+" terminal of the power supply and to the "+" terminal of the lamp
- H. Read and record the voltmeter indication
- I. With the switch still closed, measure and record the voltage across the switch
- J. With the voltmeter still connected to the switch, open the switch

JOB SHEET #2

K. Read and record the voltmeter indication with the switch open

(NOTE: Discuss the following in class:

1. The measurement across the load and across the source
2. The voltmeter reading across the closed switch
3. The voltmeter reading when the meter was connected to the "+" terminal of the power supply and the "+" terminal of the lamp
4. The difference of potential across the load and whether or not the voltage drop occurs across the load or the wire
5. The voltage reading across the open switch.)

L. Return meter and materials to proper storage area

VOLTAGE AND MEASUREMENT
UNIT V

NAME ______________________________

TEST

1. Match the terms on the right with their correct definitions.

_____a. Instrument used to measure voltage

_____b. Electrical force or pressure that causes the flow of electrical current

_____c. The unit of measurement of electromotive force

_____d. Difference in voltage measured across a component in a circuit

1. Voltage
2. Volt
3. Voltage drop
4. Voltmeter

2. Name three common sources of voltage.

a. ____

b. ____

c. ____

3. Match the symbols and abbreviations on the right with their correct definitions.

_____a. Electromotive force

_____b. Voltage source or applied voltage

_____c. Voltage or voltage drop

_____d. Voltmeter

_____e. Kilovolt

_____f. Megavolt

_____g. Millivolt

_____h. Microvolt

1. mV
2. EMF or emf
3. MV
4. V or v
5. E or e
6. VM
7. μV
8. KV or kv

4. Select principal parts of a typical voltmeter by placing an "X" in the appropriate blanks.

_____a. Connecting leads or probes

_____b. Volume control

_____c. Pressure switch

_____d. Voltage, current, resistance function switch

_____e. Direct current, alternating current function switch

_____f. Multiple use scales

_____g. Range switch

_____h. Light indicators

5. Arrange in order the procedures for using a voltmeter by placing the correct sequence numbers (1-7) in the appropriate blanks.

_____a. Read voltage on meter

_____ Use correct polarity of probes

1. Negative or common probe toward negative of power supply
2. Positive probe toward positive of power supply

_____c. Hold probes by insulated part

_____d. Remove probes

_____e. Connect voltmeter in parallel with load

_____f. Set range switch for correct range

_____g. Assure that meter will read expected voltage

6. State Kirchhoff's law of voltage.

7. Discuss current flow in a resistive circuit.

a. ______________________________

b. ______________________________

8. Discuss polarity in a resistive circuit.

a. ______________________________

b. ______________________________

9. State the formulas for voltage drops in resistive circuits.

a. ______________________________

b. ______________________________

10. Demonstrate the ability to:

    a. Measure and compare the voltage of three different batteries.

    b. Measure the voltage drops in a DC circuit.

    (NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

VOLTAGE AND MEASUREMENT
UNIT V

ANSWERS TO TEST

1. a. 4 c. 2
   b. 1 d. 3

2. a. Batteries
   b. Generators/alternators
   c. Electronic power supplies

3. a. 2 c. 4 e. 8 g. 1
   b. 5 d. 6 f. 3 h. 7

4. a, d, e, f, g

5. a. 6 e. 5
   b. 4 f. 3
   c. 1 g. 2
   d. 7

6. The algebraic sum of the voltage drops around a closed loop must equal the applied voltage

7. Discussion should include:

   a. Negative to positive
   b. Resultant potential across resistance

8. Discussion should include:

   a. End nearer negative of supply is negative
   b. End nearer positive of supply is positive

9. a. Voltages in circuit equal power source $V_1 + V_2 = E$

   b. Algebraic sum of voltage drops equal zero $V_1 + V_2 - E = 0$

10. Performance skills evaluated to the satisfaction of the instructor.

CURRENT AND MEASUREMENT
UNIT VI

UNIT OBJECTIVE

After completion of this unit, the student should be able to arrange in order the procedures for measuring current with an ammeter and convert amperes to milliamps and microamps. The student should also be able to measure and compare current at two points of a cirucit and in a circuit at two different power levels. This knowledge will be evidenced by correctly performing the procedures outlined in the assignment and job sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms associated with current and measurement with their correct definitions.
2. Define prefixes in terms of their numerical decimal equivalents and powers of ten.
3. Match symbols and abbreviations relating to current and measurement with the terms they represent.
4. Arrange in order the procedures for measuring current with a DC ammeter.
5. Convert amperes to milliamps and microamps.
6. Read ammeter indications.
7. Demonstrate the ability to:
    a. Measure and compare current at two points of a circuit.
    b. Measure and compare current in a circuit at two different voltage levels.

CURRENT AND MEASUREMENT
UNIT VI

SUGGESTED ACTIVITIES

I. Provide students with objective sheet.

II. Provide students with information, assignment, and job sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information and assignment sheets.

VI. Demonstrate and discuss procedures outlined in the job sheets.

VII. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

- A. Objective sheet
- B. Information sheet
- C. Transparency masters
    1. TM 1--Current
    2. TM 2--Series and Parallel Circuits
    3. TM 3--Prefixes
    4. TM 4--DC Current Scale and Range Switch on Typical Ammeter
    5. TM 5--Using the Ammeter in a Circuit
- D. Assignment sheets
    1. Assignment Sheet #1--Convert Amperes to Milliamps and Microamps
    2. Assignment Sheet #2--Read Ammeter Indications
- E. Answers to assignment sheets

F. Job sheets

1. Job Sheet #1--Measure and Compare Current at Two Points of a Circuit

2. Job Sheet #2--Measure and Compare Current in a Circuit at Two Different Voltage Levels

G. Test

H. Answers to test

II. References:

A. Grob, Bernard. *Basic Electronics*. 5th edition. New York: McGraw-Hill, 1977.

B. Marcus, Abraham and Samuel C. Gendler. *Basic Electronics*. Englewood Cliffs, NJ: Prentice-Hall, 1971.

CURRENT AND MEASUREMENT
UNIT VI

INFORMATION SHEET

I. Terms and definitions

   A. Current--The flow of electrons through a circuit (Transparency 1)

   B. Coulomb--A quantity of 6.28×10^{18} electrons

   C. Direct current--Current that flows through a circuit in one direction only, from the negative side of the power source through the circuit to the positive side of the power source

   D. Alternating current--Current that changes direction of flow at a certain rate

      Example: 60-hertz-per-second house current changes direction of flow 120 times each second

   E. Series circuit--A circuit in which the parts or components are connected end-to-end so that the same current flows throughout the entire circuit (Transparency 2)

   F. Parallel circuit--A circuit with multiple paths for current flow (Transparency 2)

   G. Ampere--The unit of measurement of electrical current

      (NOTE: A flow of one coulomb per second equals one ampere.)

   H. Ammeter--Instrument used for measuring electrical current

II. Numerical decimal equivalents and powers of ten prefixes (Transparency 3)

   A. Milliamp--.001 (one-thousandth) of an amp or 10^{-3}A

   B. Microamp--.000001 (one-millionth) of an amp or 10^{-6}A

   C. Picoamp--.000000000001 (one-trillionth) of an amp or 10^{-12}A

III. Symbols and abbreviations relating to current and measurement terms

   A. Current--I or i

   B. Ampere--A, a, or amp

   C. Coulomb--Q or q

   D. Ammeter-- -Ⓐ-, -ⓐ-, or -Ⓘ-

INFORMATION SHEET

E. Milliamp--ma or MA

F. Microamp-- μa or μA

G. Picoamp--pa or pA

IV. Procedures for measuring current with a DC ammeter (Transparencies 4 and 5)

A. Set range switch to expected current value

(NOTE: Measuring instruments indicate more accurately toward the center of the scale. Select a range which will allow reading the expected current in the middle half of the scale.)

B. Open the circuit by disconnecting a conductor connection or by opening a switch

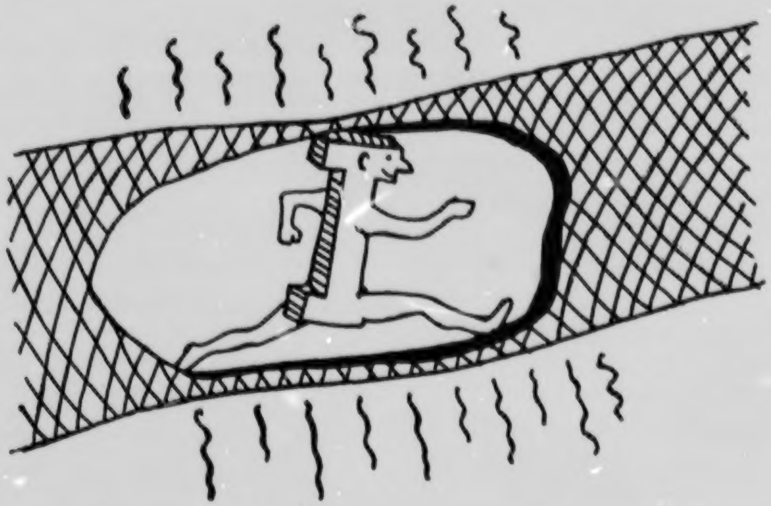
C. Observing proper polarity (negative probe toward negative side of power source, positive probe toward positive side of power source), connect ammeter in series with the circuit (Transparency 5)

D. Read current indication on proper scale, depending on range switch setting

E. Disconnect ammeter from circuit and reconnect or close circuit

(CAUTION: Never connect an ammeter in parallel to a load.)

Current



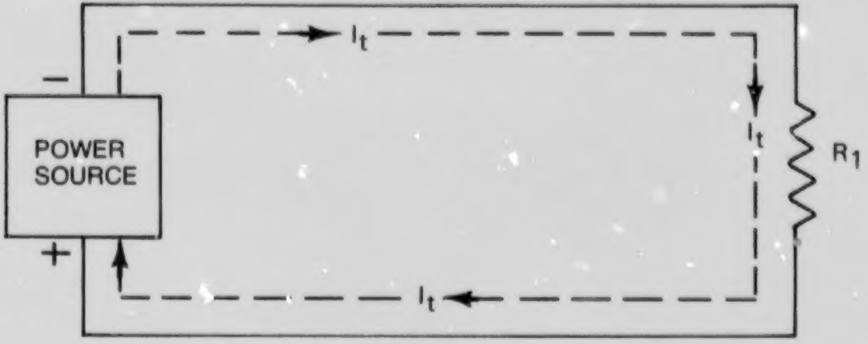
Current is the
rate of flow
of electrons

Definition: The rate of electron flow through a conductor is called current flow. A flow of 6.28×10^{18} electrons per second is called an ampere.

Symbol: I

Measured in: Amperes (1 ampere = one coulomb/second)
Instrument used to measure: Ammeter.
Symbol -ⓐ- or -Ⓘ- or -Ⓐ-

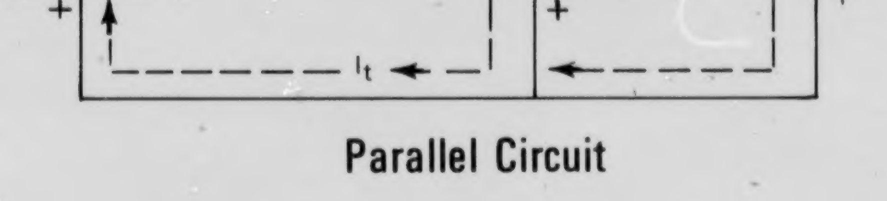
Series and Parallel Circuits


POWER SOURCE
−
+
I_t
I_t
I_t
R_1

Series Circuit

I_t = Total Current

I_1 & I_2 = Partial Current Through R_1 and R_2 of Parallel Circuit


POWER SOURCE
−
+
I_t
I_t
I_1
R_1
I_2
R_2
−
+
−
+

Parallel Circuit

Prefixes

Milli = .001 = 1/1000 = $1\text{X}10^{-3}$

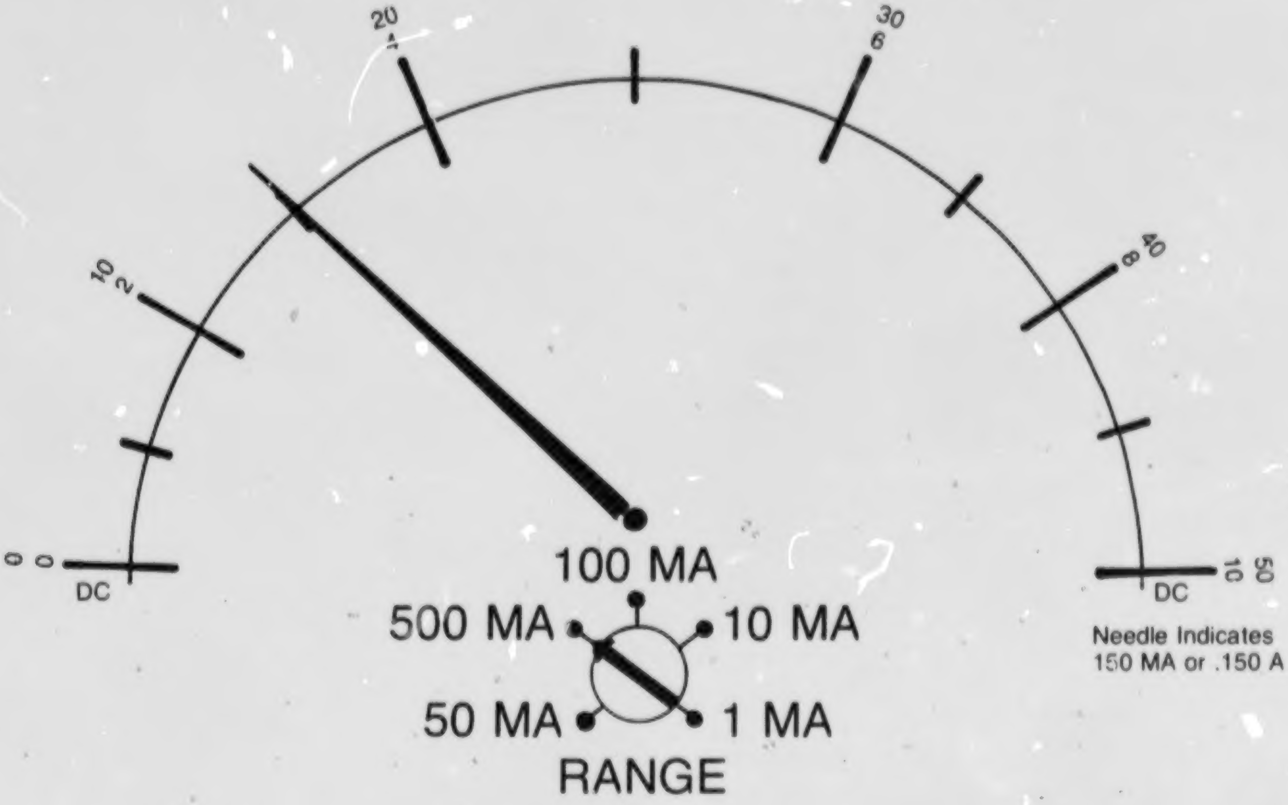
Micro = .000001 = $1\text{X}10^{-6}$ or 1/1,000,000

Pico = .000000000001 = $1\text{X}10^{-12}$ or 1/1,000,000,000,000

Kilo = 1000 = $1\text{X}10^{3}$

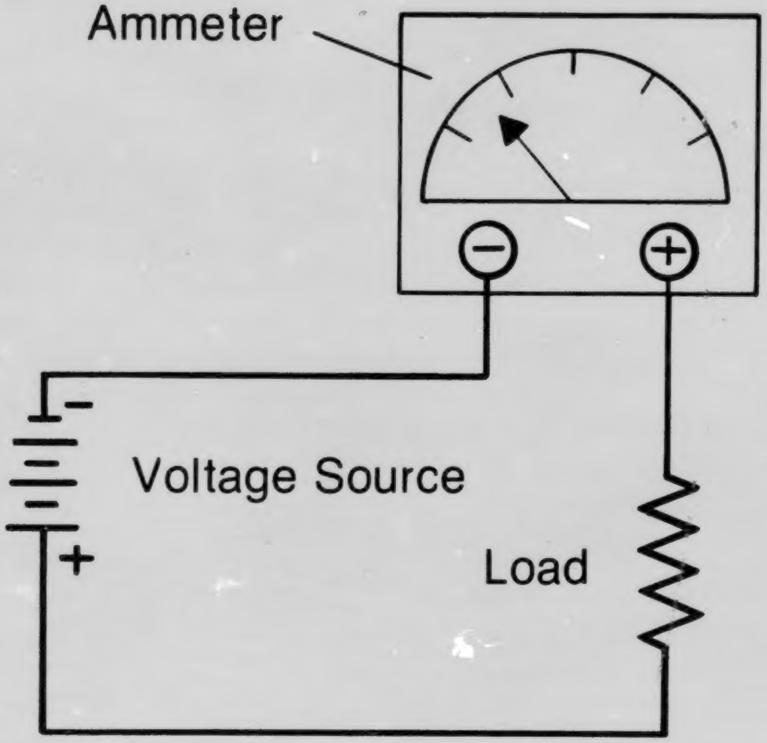
Mega = 1,000,000 = $1\text{X}10^{6}$

DC Current Scale and Range Switch on Typical Ammeter

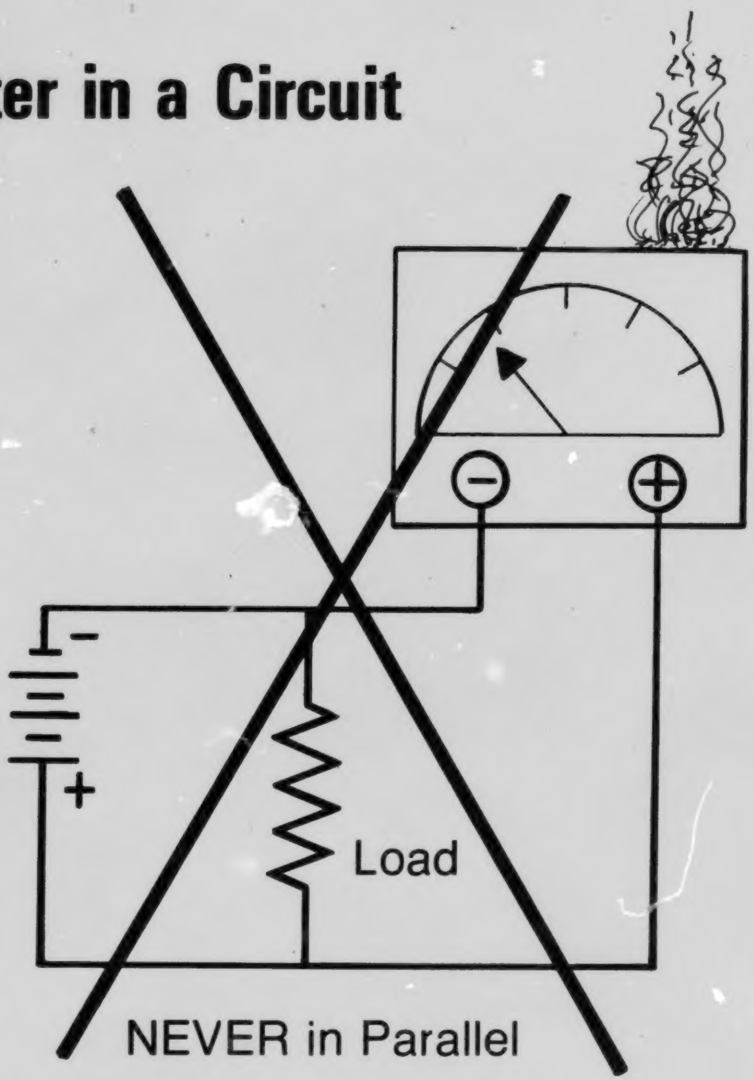

20
4
30
6
10
2
40
8
0
0
DC
50
10
DC
100 MA
500 MA
10 MA
50 MA
1 MA
RANGE

Needle Indicates
150 MA or .150 A

Using the Ammeter in a Circuit


Ammeter
−
+
−
Voltage Source
+
Load

Ammeter should be in series with load



NEVER in Parallel

CURRENT AND MEASUREMENT
UNIT VI

ASSIGNMENT SHEET #1--CONVERT AMPERES TO MILLIAMPS AND MICROAMPS

1. Convert the following amps to milliamps.

a. 1 amp = ________ milliamps d. 3654A = __________ mA

b. 2 amps = ________ milliamps e. .0214A = __________ mA

c. 3 amps = ________ milliamps f. .0036A = __________ mA

2. Convert the following amps to microamps.

a. 1 amp = ________ microamps d. 2.5A = __________ μA

b. 2 amps = ________ microamps e. .00037A = __________ μA

c. 3 amps = ________ microamps f. .0000028A = __________ μA

3. Convert the following milliamps to amps.

a. 4,000 milliamps = ________ amps d. 25.7mA = ________ A

b. 5,000 milliamps = ________ amps e. .0293mA = ______ A

c. 6,000 milliamps = ________ amps f. 263.5mA = ______ A

4. Convert the following microamps to amps.

a. 3,500 microamps = ________ amps d. 2,360,000 μA = ____ A

b. 4,500 microamps = ________ amps e. .003 μA = ________ A

c. 5,500 microamps = ________ amps f. 3.9 μA = _________ A

5. Convert as indicated.

a. .35mA = ______________ μA d. .0035A = _________ μA

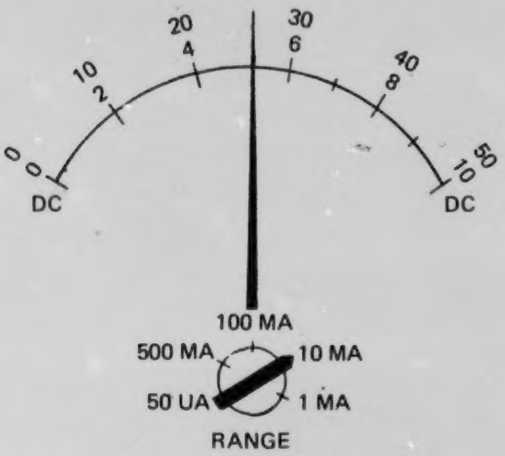
b. 635 μA = ______________ mA e. 2.45mA = _________ A

c. 2.5A = ______________ mA f. 2.93 μA = _________ A

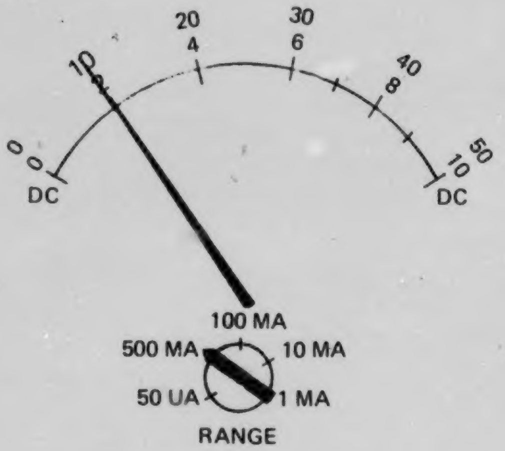
CURRENT AND MEASUREMENT
UNIT VI

ASSIGNMENT SHEET #2--READ AMMETER INDICATIONS

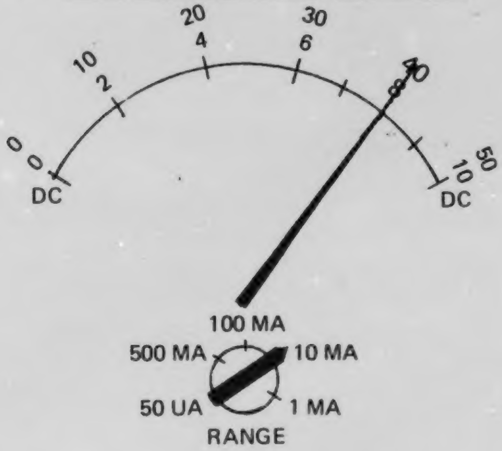
Directions: Write down the current reading for each of the ammeter indications.


0 0
10 2
20 4
30 6
40 8
50 10
DC
DC
100 MA
500 MA
10 MA
50 UA
1 MA
RANGE

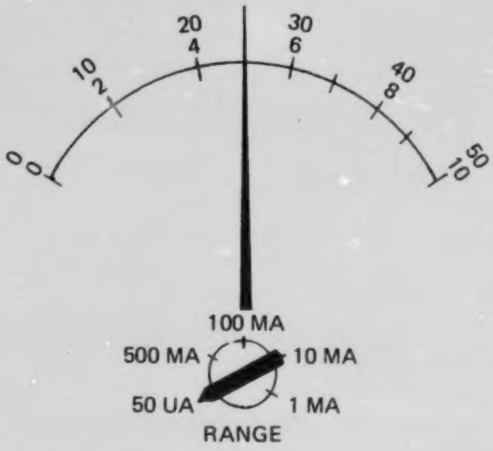
a. ______________________


0 0
10 2
20 4
30 6
40 8
50 10
DC
DC
100 MA
500 MA
10 MA
50 UA
1 MA
RANGE

b. ______________________


0 0
10 2
20 4
30 6
40 8
50 10
DC
DC
100 MA
500 MA
10 MA
50 UA
1 MA
RANGE

c. ______________________


0 0
10 2
20 4
30 6
40 8
50 10
100 MA
500 MA
10 MA
50 UA
1 MA
RANGE

d. ______________________

CURRENT AND MEASUREMENT
UNIT VI

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

1. a. 1,000
   b. 2,000
   c. 3,000
   d. 3,654,000
   e. 21.4
   f. 3.6

2. a. 1,000,000
   b. 2,000,000
   c. 3,000,000
   d. 2,500,000
   e. 370
   f. 2.8

3. a. 4
   b. 5
   c. 6
   d. .0257
   e. .0000293
   f. .2635

4. a. .0035
   b. .0045
   c, .0055
   d. 2.36
   e. .000000003
   f. .0000039

5. a. 350
   b. 6.35
   c. 2500
   d. 3500
   e. .00245
   f. .00000293

Assignment Sheet #2

a. 5 ma

b. 100 ma

c. .8 ma

d. 20 μa

CURRENT AND MEASUREMENTS
UNIT VI

JOB SHEET #1--MEASURE AND COMPARE CURRENT AT TWO POINTS OF A CIRCUIT

I. Tools and equipment

   A. DC ammeter (or multimeter)

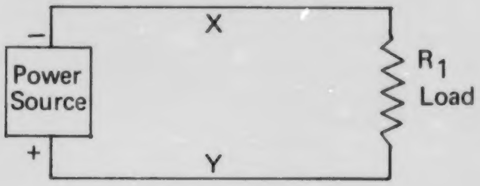
   B. DC power source

   C. Load (lamp or other resistance)

II. Procedure

   A. Wire the schematic in Figure 1; set power source at 1 1/2 vdc

FIGURE 1



   B. Measure and record current at point X on the schematic

   C. Measure and record current at point Y on the schematic

   D. Compare current measurement

   (NOTE: The following questions may be used for discussion:

   1. Was the current the same or different at point X and point Y? Why?

   2. Do you connect an ammeter differently than you do a voltmeter? If so, how? Why?

   3. Do you have to know the + and - connections of a DC ammeter? Why?)

   G. Return meter and materials to proper storage area

CURRENT AND MEASUREMENT
UNIT VI

JOB SHEET #2--MEASURE AND COMPARE CURRENT IN A CIRCUIT AT TWO DIFFERENT VOLTAGE LEVELS

I. Tools and equipment

A. DC ammeter (or multimeter)

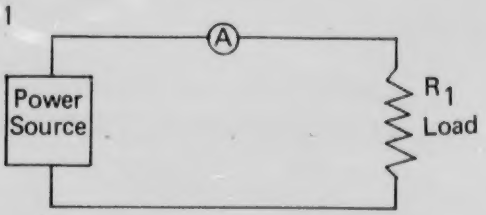
B. DC power source

C. Load (lamp or other resistance)

II. Procedure

A. Connect the circuit as shown in Figure 1; set DC power source at 1 1/2 vdc

FIGURE 1



B. Measure and record the current in the circuit amperage

C. Increase power source to 3 vdc

D. Measure and record the current

E. Compare current measurements

(NOTE: The following questions may be used for discussion:

1. Is there more current at 1 1/2 vdc or at 3 vdc power source?
2. With the same load, what happens to the current in a circuit when you change the voltage applied to the circuit?
3. What happens if the polarity of the power source is reversed?
4. If a lamp was used as the load, did (or would) the lamp glow brighter when the voltage was increased? Why?)

F. Return meter and materials to proper storage areas

CURRENT AND MEASUREMENT
UNIT VI

NAME ______________________________

TEST

1. Match on the right terms with their definitions.

______ a. The unit of measurement of electrical current

______ b. Current that flows through a circuit in one direction only, from the negative side of the power source through the circuit to the positive side of the power source

______ c. The flow of electrons through a circuit

______ d. Instrument used for measuring electrical current

______ e. A circuit with multiple paths for current flow

______ f. A circuit in which the parts or components are connected end-to-end so that the same current flows throughout the entire circuit

______ g. A quantity of 6.28×10^{18} electrons

______ h. Current that changes direction of flow at a certain rate

1. Current
2. Coulomb
3. Direct current
4. Alternating current
5. Series circuit
6. Parallel circuit
7. Ampere
8. Ammeter

2. Define each of the following prefixes in terms of both the numerical decimal equivalent and powers of ten.

	Numerical decimal equivalent	Powers of ten
a. Milliamp	______________	____________
b. Microamp	______________	____________
c. Picoamp	______________	____________

3. Match the symbols and abbreviations on the right with the terms on the left which they represent.

   ______a. Current
   ______b. Ampere
   ______c. Coulomb
   ______d. Ammeter
   ______e. Milliamp
   ______f. Microamp
   ______g. Picoamp

   1. ma or MA
   2. I or i
   3. A, a, or amp
   4. μa or μA
   5. pa or pA
   6. -Ⓐ-,-ⓐ-, or,-Ⓘ-
   7. Q or q

4. Arrange in order the procedures for measuring current with a DC ammeter by placing the correct sequence numbers in the appropriate blanks.

   ______a. Observing proper polarity, connect ammeter in series with the circuit
   ______b. Disconnect ammeter from circuit and reconnect or close circuit
   ______c. Open the circuit by disconnecting a conductor connection or by opening a switch
   ______d. Set range switch to expected current value
   ______e. Read current indication on proper scale, depending on range switch setting

5. Convert amperes to milliamps and microamps.

6. Read ammeter indications.

7. Demonstrate the ability to:

   a. Measure and compare current at two points of a circuit

   b. Measure and compare current in a circuit at two different voltage levels

   (NOTE: If these activities have not been accomplished prior to the test, ask the instructor when they should be completed.)

CURRENT AND MEASUREMENT
UNIT VI

ANSWERS TO TEST

1. a. 7 e. 6
   b. 3 f. 5
   c. 1 g. 2
   d. 8 h. 4

2. a. .001 of an amp or 10^{-3}A

   b. .000001 of an amp or 10^{-6}A

   c. .000000000001 of an amp or 10^{-12}A

3. a. 2 e. 1
   b. 3 f. 4
   c. 7 g. 5
   d. 6

4. a. 3 d. 1
   b. 5 e. 4
   c. 2

5. Evaluated to the satisfaction of the instructor.

6. Evaluated to the satisfaction of the instructor.

7. Performance skills evaluated to the satisfaction of the instructor.

POWER
UNIT VII

UNIT OBJECTIVE

After completion of this unit, the student should be able to compute current using the power formula, determine the power used in a resistive circuit, and determine the function of fuses and resistor power ratings. This knowledge will be evidenced by correctly performing the procedures outlined on the assignment and job sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms associated with power and measurement to their definitions.
2. Match power abbreviations with their correct terms.
3. State three forms of the formula used to compute electrical power.
4. Arrange in proper sequence the procedures for power measurement using a DC wattmeter.
5. Select true statements concerning resistor wattage rating.
6. List electrical power safety precautions.
7. Distinguish between direct and inverse proportions involved in power formulas.
8. Demonstrate the ability to:
    a. Compute current using the power formula.
    b. Determine the power used in a resistive circuit.
    c. Determine the function of fuses and resistor power ratings.

POWER
UNIT VII

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information, assignment, and job sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information and assignment sheets.

VI. Demonstrate and discuss the procedures outlined in the job sheets.

VII. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

- A. Objective sheet
- B. Information sheet
- C. Transparency masters
  - 1. TM 1--Power
  - 2. TM 2--Power Measurement Using a DC Wattmeter
  - 3. TM 3--Power Rating of Resistors
- D. Assignment Sheet #1--Compute Power from the Power Formula
- E. Answers to assignment sheet
- F. Job sheets
  - 1. Job Sheet #1--Compute Current Using the Power Formula
  - 2. Job Sheet #2--Determine Power Used in a Resistive Circuit
  - 3. Job Sheet #3--Demonstrate the Function of Fuses and Resistor Power Ratings
- G. Test
- H. Answers to test

II. References:

A. Grob, Bernard, *Basic Electronics*, 5th edition, New York: McGraw-Hill Book Co., 1977.

B. Marcus, Abraham, and Samuel E. Gendler. *Basic Electronics*. Englewood Cliffs, NJ: Prentice-Hall, 1971.

POWER
UNIT VII

INFORMATION SHEET

I. Terms and definitions

A. Electrical power--The rate of doing work by electrons moving through a resistive material (Transparency 1)

B. Watt--The unit of measurement for power

(NOTE: One watt of power is expended when one ampere of current is flowing through one ohm of resistance.)

C. Kilowatt--1,000 watts

D. Kilowatthours--Energy, in kilowatts, multiplied by the time in hours

Example: A circuit drawing 1.5 kilowatts of power for 5 hours uses 7.5 kilowatthours of electrical energy

E. Fuse--An electrical device which protects a circuit from excessive power or current

Example: Excessive current melts the metal fuse element and opens the circuit

F. Circuit breaker--An electrical switch which protects a circuit from excessive power or current

(NOTE: Heat expands a thermal element in the breaker and it opens the circuit. A blown electrical fuse must be replaced with a new one; however, a circuit breaker can be reset.)

G. Work--Measured in foot-pounds without any reference to time

(NOTE: Work and energy are essentially the same.)

H. Power--The rate of doing work

II. Terms and abbreviations for power

A. Power--P

B. Watt--W

C. Kilowatt--kW

INFORMATION SHEET

III. Forms of the formula used to compute electrical power

   A. When current and voltage are known: $P = EI$

   B. When current and resistance are known: $P = I^2R$

   C. When voltage and resistance are known: $P = E^2/R$

IV. Sequence used for power measurement using a DC wattmeter (Transparency 2)

   A. With circuit power turned off, connect the current (I) terminals of wattmeter in series with circuit load

   (CAUTION: Observe correct polarity when connecting the wattmeter leads to DC circuits. The positive lead must be toward the positive side of the circuit power supply, and negative lead toward negative side of power supply.)

   B. Connect the voltage (E) terminals of wattmeter across load with power off

   C. Turn on circuit power

   D. Read and record power value in watts indicated on wattmeter

   E. Turn off circuit power and disconnect wattmeter

V. Wattage rating of resistors (Transparency 3)

   A. Resistors have ohm values and wattage ratings

   B. Wattage rating indicates the maximum amount of power that a resistor can handle before it burns up

   C. Use a wattage safety factor of 2 when choosing resistors; the wattage rating should be double the expected power level of the circuit

   D. Resistor size generally indicates wattage rating

      1. Small carbon resistors are generally used in circuits which operate well below 2 watts

      2. Larger wire wound resistors are capable of dissipating the heat generated by higher power levels

VI. Electrical power safety precautions

   A. Circuit safety precautions

      1. Never install a fuse or circuit breaker whose current rating is higher or whose voltage rating is lower than specified for a particular circuit

      2. Never bypass or defeat a fuse or circuit breaker

INFORMATION SHEET

B. Worker safety precautions with live circuits

1. Work with well-insulated tools whenever possible

2. Avoid completing a circuit through the body

VII. Power formula proportions

A. Direct proportion--A relationship by which a change in one quantity produces the same direction of change in another quantity

Example: In the power formula $P = EI$, if the current remains constant but the voltage is decreased, power is also decreased. In this formula, power and voltage are directly proportional

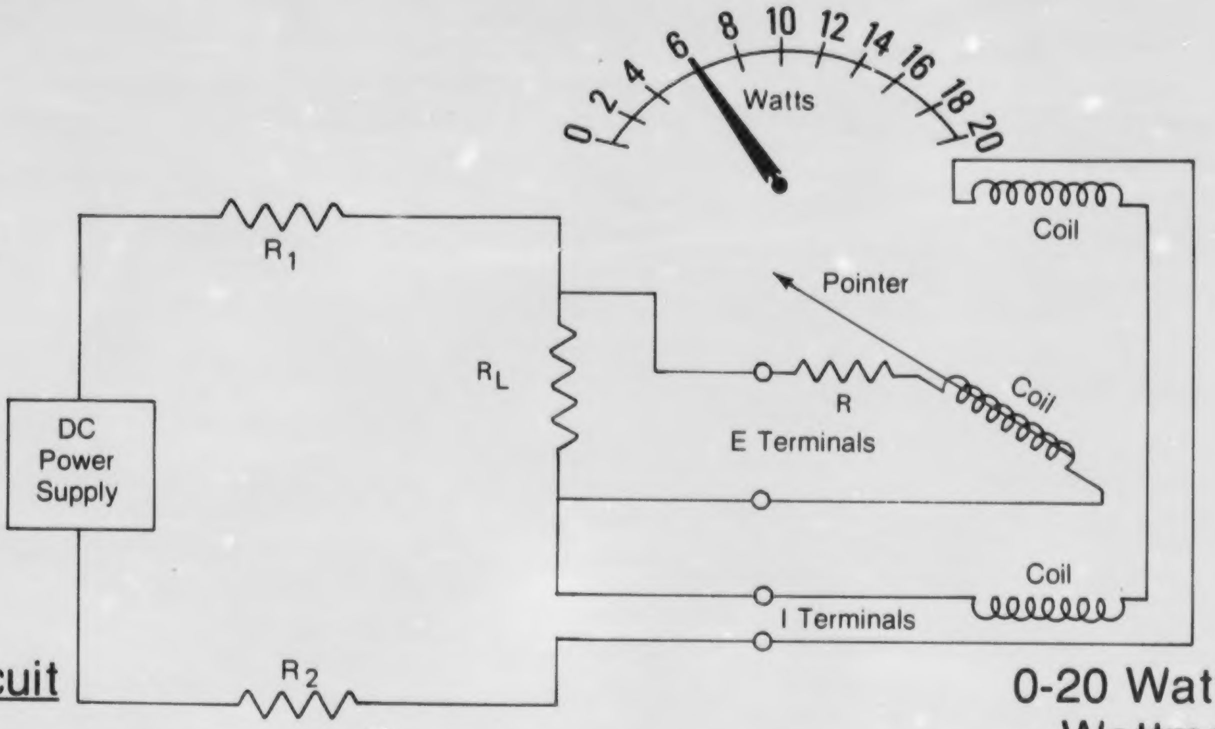
B. Inverse proportion--A relationship by which a change in one quantity produces the opposite direction of change in another quantity

Example: In the power formula $P = E^2/R$, if voltage remains constant but resistance is increased, power is decreased. In this formula, power and resistance are inversely proportional

Power

- Is defined as the rate of doing work (w/t)
- Has the symbol "P"
- Can be calculated with formulas $P=IE$, $P=I^2 R$, $P=E^2/R$ Watt's Law
- Is measured in watts 1 watt=1 ampere x 1 volt
- Is measured by a wattmeter

Power Measurement Using A DC Wattmeter


0
2
4
6
8
10
12
14
16
18
20
Watts
R1
RL
DC Power Supply
R2
Pointer
R
Coil
Coil
Coil
E Terminals
I Terminals

DC Circuit

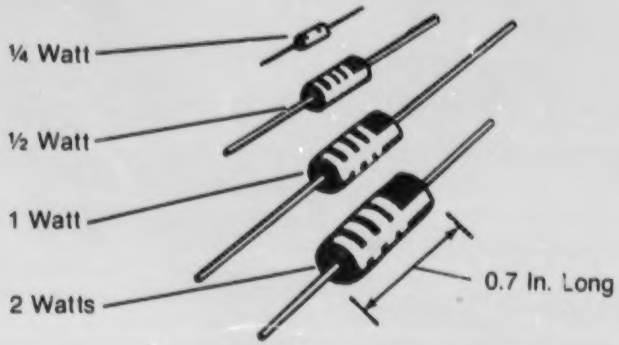
0-20 Watts DC Wattmeter

NOTE: E Terminals of Wattmeter are Connected Across the Load (In Parallel)

I Terminals are Connected In Line with the Load (In Series)

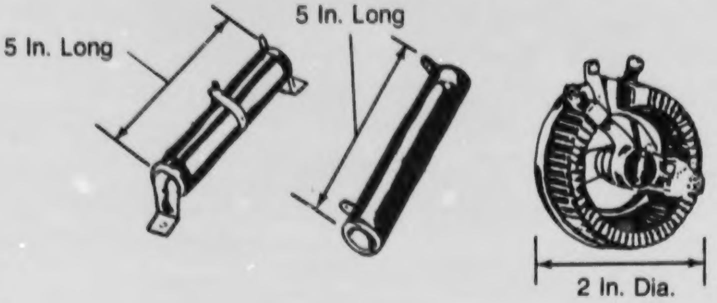
Power Rating of Resistors

Power Rating


¼ Watt
½ Watt
1 Watt
2 Watts
0.7 In. Long

Carbon Resistors

Power Rating: All 3, 50 Watts


5 In. Long
5 In. Long
2 In. Dia.

Wire Wound Resistors

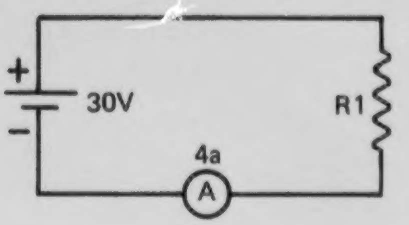
NOTE: Larger Wire Wound Resistors Have Higher Power Ratings

POWER
UNIT VII

ASSIGNMENT SHEET #1--COMPUTE POWER FROM THE POWER FORMULA

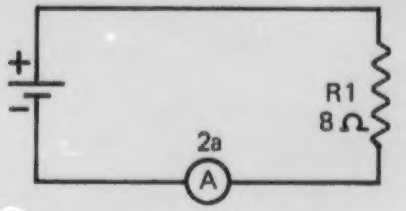
Directions: Given the formulas for power, $P = EI$ when current and voltage are known, $P = I^2R$ when current and resistance are known, and $P = E^2/R$ when voltage and resistance are known, study the following schematics and answer the questions below them.

a.



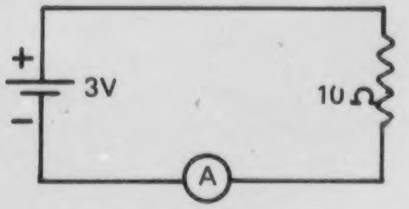
1. State the power formula needed to solve for power.
2. Solve for P.

b.



1. State the power formula needed to solve for power.
2. Solve for P.

c.



1. State the power formula needed to solve for power.
2. Solve for P.

POWER
UNIT VII

ANSWERS TO ASSIGNMENT SHEET #1

a. 1. $P = EI$

   2. 120 watts

b. 1. $P = I^2R$

   2. 32 watts

c. 1. $P = E^2/R$

   2. $P = .9$ watts

POWER
UNIT VII

JOB SHEET #1--COMPUTE CURRENT USING THE POWER FORMULA

I. Equipment and materials

A. Lamp holder with 100-watt bulb

B. Lamp holder with 40-watt bulb

C. 110-volt power source

(NOTE: Smaller voltage lamps can be used with an appropriate power supply.)

II. Procedure

A. Plug both lamps into 110-volt line and turn switches on at the same time

B. Let lamps heat up for a brief time

C. Feel both lamps and note which is hotter

D. Determine which lamp is using more power

(NOTE: The hotter lamp is using more power.)

E. Determine which lamp is using more current

F. Determine which lamp has the lower resistance

G. Using the formula $P = EI$, compute the current flowing through each lamp

H. Return lamps to proper storage area

POWER
UNIT VII

JOB SHEET #2--DETERMINE POWER USED IN A RESISTIVE CIRCUIT

I. Equipment and materials

A. Adjustable DC power supply (0-30 volts)

B. DC wattmeter (0-20 watts)

C. 75-ohm, 20-watt resistor

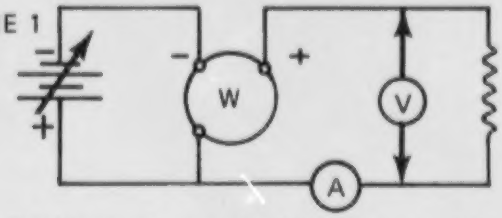
D. Ammeter

E. DC Voltmeter and ohmmeter (multimeter)

II. Procedure

A. Leaving the power off, connect the following circuit (Figure 1)

FIGURE 1



B. Double check your circuit for correct wiring

C. Turn power on

D. Apply 15 volts across the resistor

E. Read and record the voltage, current and wattmeter indications

F. Increase the power supply to 25 volts

G. Read and record E, I, and P

H. Increase the power supply to 30 volts

I. Read and record E, I, and P

J. Turn the power supply off

K. Disconnect the circuit

L. Read its value with your ohmmeter

M. Using the three forms of the power formula, compute the power for the E, I, and R values at 15 volts, 25 volts, and 30 volts

JOB SHEET #2

N. Compare the computed values with the wattmeter readings

(NOTE: The following questions may be used for discussion:

1. What causes the differences between computed values and wattmeter indications?
2. Did the resistance remain constant during this experiment? Did the current remain constant? Compare the changing voltage with the power consumed by the resistor. Is the relationship a direct proportion or indirect proportion?
3. Would the same power be consumed if the load were reversed? Why?
4. When the voltage was doubled (15v to 30v), how much did power increase?)

O. Return meters and materials to proper storage area

POWER
UNIT VII

JOB SHEET #3--DETERMINE THE FUNCTION OF FUSES AND RESISTOR POWER RATINGS

(NOTE: The instructor may desire to conduct this job as a demonstration.)

I. Equipment and materials

   A. Variable power supply (minimum 10v, 1A capability)

   B. 1,000-ohm, 1/2-watt resistor

   C. 10-ohm, 1/2-watt resistor (expendable)

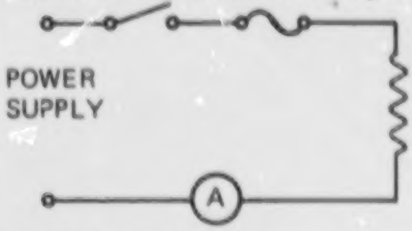
   E. One 1/2-amp fuse (expendable)

   F. DC ammeter (1-amp capability)

II. Procedure

   A. Connect the power supply, switch, 1,000-ohm resistor, ammeter, and 1/2-amp fuse in series as follows: (Figure 1)

FIGURE 1



   B. Turn on the power supply

   C. Adjust to 10 volts

   D. Turn on the switch

   E. Read and record the current indication on the ammeter

   F. Turn the power supply to zero

   G. Open the switch

   H. Replace the 1,000-ohm resistor with the 10-ohm resistor

   (CAUTION: Set range switch, if applicable, to 1 ampere or more.)

   I. Close the switch

   J. Adjust the power supply to 10 volts

   K. Observe the fuse and record what you observe

JOB SHEET #3

L. Connect a wire across the fuse and observe the 10-ohm resistor

(NOTE: The following questions should be used for discussion:

1. How did you know that your resistors were 1/2-watt resistors? Explain.
2. How much power was applied to the 1,000-ohm resistor? ($P = I^2R$)
3. Explain why the fuse blew when 10 volts were applied to the 10-ohm resistor.
4. Explain what happened to the resistor. How much power was being applied after you shorted the fuse?
5. If you had to use a 10-ohm resistor with 10 volts applied, what would you do?)

POWER
UNIT VII

NAME ______________________________

TEST

1. Match the terms on the right to the correct definitions.

______a. An electrical device which protects a circuit from excessive power or current

______b. The unit of measurement for power

______c. An electrical switch which protects a circuit from excessive power or current

______d. The rate of doing work by electrons moving through a resistive material

______e. 1,000 watts

______f. Energy, in kilowatts, multiplied by the time in hours

______g. The rate of doing work

______h. Measured in foot-pounds without any reference to time

1. Electrical power
2. Watt
3. Kilowatt
4. Kilowatthours
5. Fuse
6. Circuit breaker
7. Power
8. Work

2. Match the power terms on the right with their correct abbreviations.

______a. kW

______b. P

______c. W

1. Power
2. Watt
3. Kilowatt

3. State the three forms of the formula used to compute electrical power.

a. When current and voltage are known:

b. When current and resistance are known:

c. When voltage and resistance are known:

4. Arrange in proper sequence the following procedures for power measurement using a DC wattmeter by numbering them 1 through 5.

   _____a. Read and record power value in watts indicated on wattmeter

   _____b. Turn on circuit power

   _____c. Connect the voltage (E) terminals of wattmeter across load with power off

   _____d. Turn off circuit power and disconnect wattmeter

   _____e. With circuit power turned off, connect the current (I) terminals of wattmeter in series with circuit load

5. Select the statements that are true concerning resistor wattage rating by placing an "X" in the appropriate blanks.

   _____a. Most resistors do not have a wattage rating

   _____b. The wattage rating indicates the maximum amount of power that a resistor can handle before it burns up

   _____c. A wattage safety factor of 1 should be used when choosing resistors

   _____d. Larger wire wound resistors are capable of dissipating the heat generated by higher power levels

6. List two circuit safety precautions and one worker safety precaution.

   a. Circuit safety precautions

      1)

      2)

   b. Worker safety precautions with live circuits

7. Distinguish between direct and inverse proportion involved in power formulas by placing an "X" next to the description of inverse proportion.

   _____a. A relationship by which a change in one quantity produces the opposite direction of change in another quantity

   _____b. A relationship by which a change in one quantity produces the same direction of change in another quantity

8. Demonstrate the ability to:

   a. Compute current using the power formula.

   b. Determine the power used in a resistive circuit.

   c. Determine the function of fuses and resistor power ratings.

   (NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

POWER
UNIT VII

ANSWERS TO TEST

1. a. 5
   b. 2
   c. 6
   d. 1
   e. 3
   f. 4
   g. 7
   h. 8

2. a. 3
   b. 1
   c. 2

3. a. $P = EI$

   b. $P = I^2R$

   c. $P = E^2/R$

4. a. 4
   b. 3
   c. 2
   d. 5
   e. 1

5. b, d

6. a. Both of the following:

   1) Never install a fuse or circuit breaker whose current rating is higher or whose voltage rating is lower than specified for a particular circuit

   2) Never bypass or defeat a fuse or circuit breaker

   b. Any one of the following:

   1) Work with well-insulated tools whenever possible

   2) Avoid completing a circuit through the body

7. a

8. Performance skills evaluated to the satisfaction of the instructor.

CONDUCTORS AND INSULATORS
UNIT VIII

UNIT OBJECTIVE

After completion of this unit, the student should be able to describe functional features of electrical conductors and electrical insulators and select true statements about wire sizes and gauge numbers, the properties of conducting materials, and wire resistance. The student should also be able to calculate wire diameters, cross-sectional areas, and resistance. This knowledge will be evidenced by correctly performing the procedures outlined on the assignment sheet and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, student should be able to:

1. Match terms associated with conductors and insulators with their definitions.
2. Distinguish between conductors, semiconductors, and insulators.
3. Describe four functional features of electrical conductors.
4. Describe four functional features of electrical insulators.
5. Name major applications of conductors.
6. Name types of wire conductors.
7. Select statements that are true about wire sizes and gauge numbers.
8. Select statements that are true about the properties of conducting materials.
9. Select statements that are true about wire resistance.
10. Name the desirable properties of wire insulation.
11. Calculate wire diameters, cross-sectional areas, and resistance.

CONDUCTORS AND INSULATORS
UNIT VIII

SUGGESTED ACTIVITIES

I. Provide students with objective sheet.

II. Provide students with information and assignment sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information and assignment sheets.

VI. Display various types and sizes of conducting wires, cables, dielectric materials (capacitors may be opened up for this purpose), and insulating material, and discuss the function and properties of each.

VII. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:
  A. Objective sheet
  B. Information sheet
  C. Transparency masters
    1. TM 1--Conductors and Insulators
    2. TM 2--Conductor Resistance and Voltage Drop
    3. TM 3--Dielectric Strength of Common Insulators
    4. TM 4--Common Uses of Conductors
    5. TM 5--Types of Wire Conductors
    6. TM 6--Standard Copper Wire Gauge Sizes
    7. TM 7--Properties of Conducting Materials
  D. Assignment Sheet #1--Calculate Wire Diameters, Cross-sectional Areas, and Resistance

E. Answers to assignment sheet

F. Test

G. Answers to test

II. References:

A. Grob, Bernard. *Basic Electronics.* New York: McGraw-Hill Co., 1977.

B. Marcus, Abraham. *Basic Electronics.* Englewood Cliffs, NJ: Prentice-Hall, Inc., 1971.

C. *Reference Data for Radio Engineers.* New York: Howard W. Sams & Co., Inc., 1974.

CONDUCTORS AND INSULATORS
UNIT VIII

INFORMATION SHEET

I. Terms and definitions

A. Resistivity or specific resistance--The electrical resistance of a rod of conducting material having a specified length and cross-sectional area

B. Conductivity--The capacity of a conducting rod of unit length and cross-sectional area to allow electrical current flow

C. Semiconductor--A material having relatively high resistance at room temperature, whose electrical characteristics can be changed and controlled by various techniques, such as by adding other elements called "impurities"

Examples: Germanium and silicon which function as transistors and diodes after the impurities arsenic or gallium are added to them

D. Dielectric--A material of very high resistance which is capable of holding or storing an electrical charge

Examples: Mica, paper, and ceramics, which are used in the construction of capacitors

E. Mil--One thousandth (0.001) of an inch

F. Circular mil (cmil) area--The cross-sectional area of a wire calculated by squaring the wire diameter in mils

Example: The cmil area of a conductor having a diameter of 7.0 mils is 49.0 cmils (7.0 squared)

(NOTE: This method of calculating cross-sectional area is used only for conducting wires, and is done as a convenience to avoid having to calculate cross-sectional area by means of the metric system and formula.)

II. Conducting and insulating materials (Transparency 1)

A. Conductors (low resistance)

1. Silver
2. Copper
3. Aluminum

INFORMATION SHEET

   4. Gold
   5. Tungsten
   6. Nickel
   7. Iron

B. Semiconductors (medium resistance)
   1. Germanium
   2. Silicon

C. Insulators (high resistance)
   1. Air or vacuum
   2. Bakelite
   3. Glass
   4. Mica
   5. Paper
   6. Rubber
   7. Shellac

III. Functional features of electrical conductors (Transparency 2)
   A. Many free electrons (for conduction of electricity)
   B. Low resistance to electrical current
   C. Little voltage (IR) drop
   D. Low power dissipation

IV. Functional features of electrical insulators (Transparency 3)
   A. Few free electrons (for conduction of electricity)
   B. High resistance to electrical current
   C. Hold or store an electrical charge
   D. High dielectric strength (high voltage breakdown point)

INFORMATION SHEET

V. Applications of conductors (Transparency 4)

- A. Wiring
- B. Switches
  - 1. Knife
  - 2. Toggle
  - 3. Rotary
  - 4. Pushbutton
- C. Pilot lamp filaments
  - 1. Bayonet
  - 2. Screw-type
- D. Fuses and circuit breakers

VI. Types of wire conductors (Transparency 5)

- A. Solid
- B. Stranded
- C. Wire braid
- D. Coaxial cable
- E. Twin-lead cable
- F. Flat cable

VII. Wire sizes and gauge numbers (Transparency 6)

- A. American Standard Wire Gauge is used to check wire sizes
- B. Wire gauge chart
  - 1. Gauge numbers range from 1 to 40
  - 2. Wire diameter is measured in mils (0.001 in.)
  - 3. Cross-sectional area is measured in:
    - a. Circular mils
    - b. The diameter in mils squared
  - 4. Resistance is measured in ohms per 1000 ft

INFORMATION SHEET

C. The higher the gauge number of a wire:

  1. The smaller its wire diameter

  2. The smaller its cross-sectional area

  3. The higher its resistance

VIII. Properties of conducting materials (Transparency 7)

  A. Specific resistance or resistivity

    1. Symbol - ρ (Greek letter "rho")

    2. Expressed in circular mil-ohms per foot (cmil-ohms/foot)

    (NOTE: Use of the circular mil for determining wire resistivity is a convenience because it eliminates the need to calculate the cross-sectional area of the wire using the metric formula.)

  B. Temperature coefficient

    1. Symbol -- α (Greek letter "alpha")

    2. Resistivity changes with temperature

      a. Positive α -- Resistivity increases with temperature

      b. Negative α -- Resistivity decreases with temperature

  C. Melting point--Varies with materials

IX. Wire resistance

  A. Principles

    1. The thicker the wire, the less its resistance

    2. The longer the wire, the higher its resistance

INFORMATION SHEET

B. Formula for wire resistance:

$R = \rho \frac{L}{A}$, where R = resistance

ρ = resistivity (see Transparency 7)

L = length

A = cross-sectional area in circular mils (see Transparency 6)

Example: What is the total resistance of 100 ft of No. 20 copper wire at room temperature?

The cross-sectional area of No. 20 wire is 1,022 cmils (Transparency 6)

The resistivity of (ρ) of copper at room temperature is 10.4 cmil-ohms per foot (Transparency 7)

Using the formula:

$$R = \rho \frac{L}{A} = 10.4 \frac{\text{cmil-ohm}}{\text{ft}} \times \left(\frac{100 \text{ ft}}{1{,}022 \text{ cmils}}\right)$$

$$R = 10.4 \frac{100}{1022} \text{ ohm}$$

$$R = 1.02 \text{ ohms}$$

X. Desirable properties of wire insulation

A. High resistance

B. Toughness

C. Flexibility

D. Non-brittleness with aging

Conductors and Insulators

Insulators

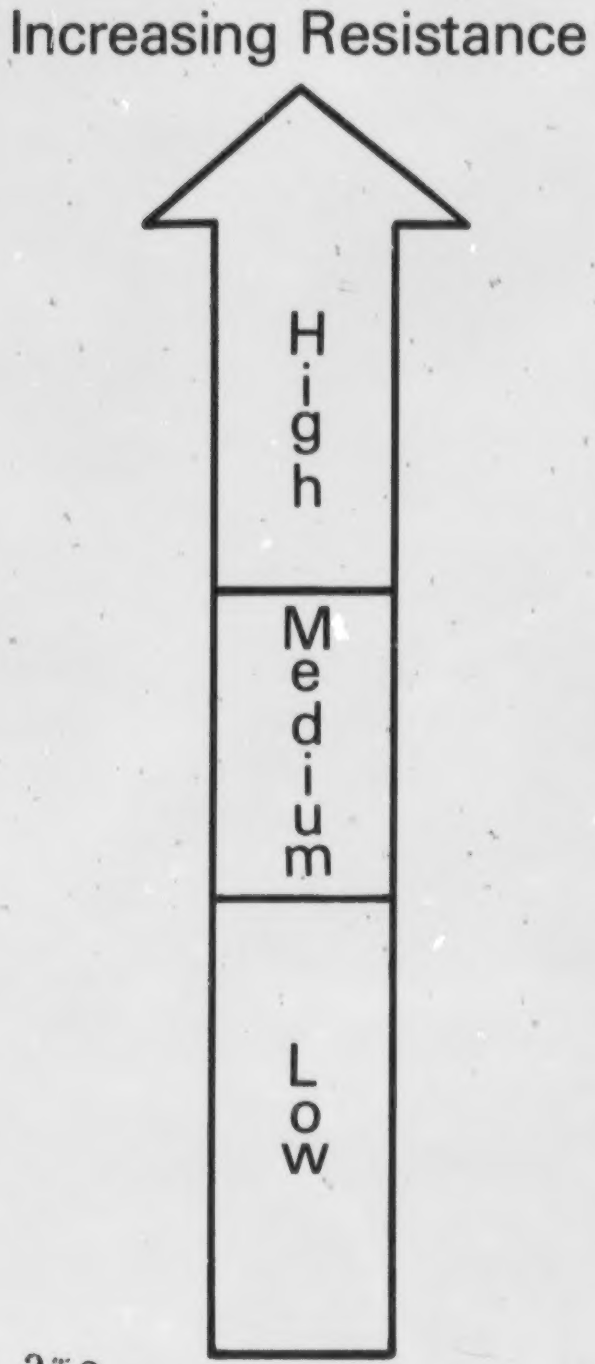
- Air or Vacuum
- Fiber
- Bakelite
- Rubber
- Paper
- Shellac
- Glass
- Mica

Semiconductors

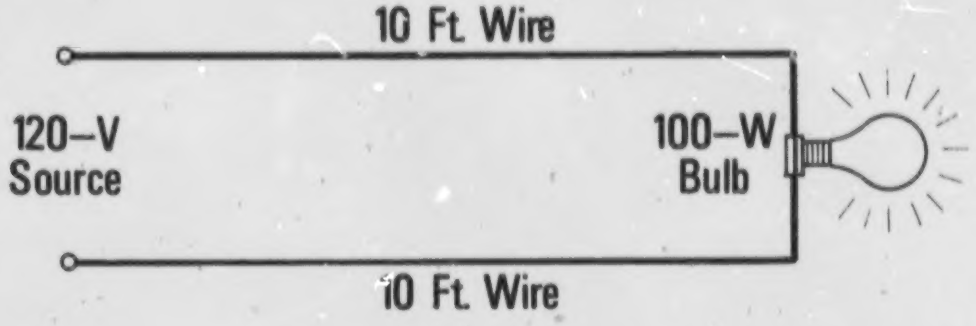
- Germanium
- Silicon

Conductors

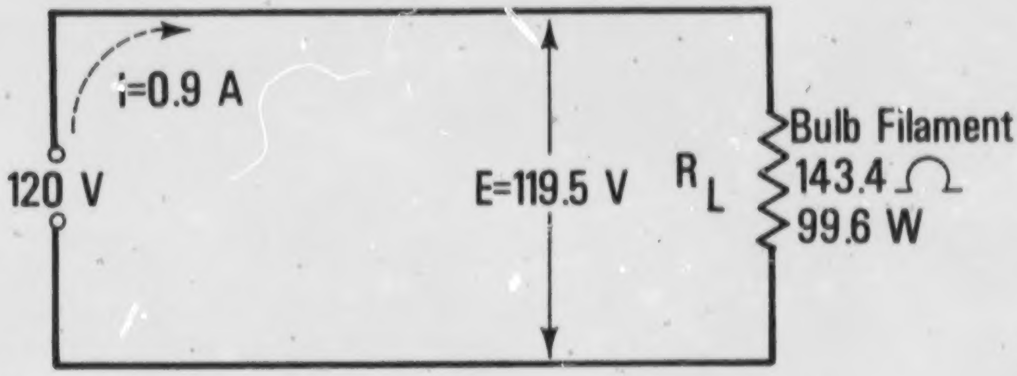
- Silver
- Copper
- Gold
- Aluminum
- Tungsten
- Nickel
- Iron


Increasing Resistance
High
Medium
Low

Conductor Resistance and Voltage Drop


10 Ft. Wire
120–V
Source
100–W
Bulb
10 Ft. Wire

Wiring Diagram


I=0.9 A
120 V
E=119.5 V
R_L
Bulb Filament
143.4 Ω
99.6 W

Schematic

Conductors

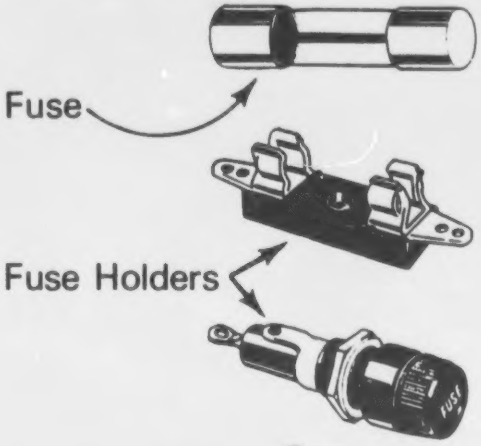
R=0.6 Ω
IR=0.54 V
P=0.49 W

Dielectric Strength of Common Insulators

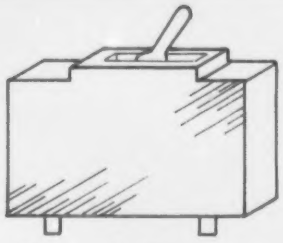
MATERIAL	DIELECTRIC STRENGTH, V/MIL	MATERIAL	DIELECTRIC STRENGTH, V/MIL
Air or vacuum	20	Paraffin wax	200-300
Bakelite	300-550	Phenol, molded	300-700
Fiber	150-180	Polystyrene	500-760
Glass	335-2,000	Porcelain	40-150
Mica	600-1,500	Rubber, hard	450
Paper	1,250	Shellac	900
Paraffin oil	380		

Common Uses of Conductors

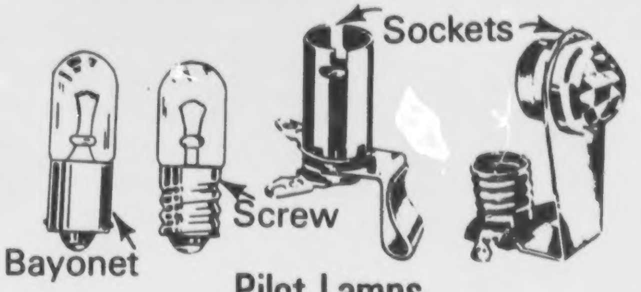
Conducting Wires


Fuse
Fuse Holders

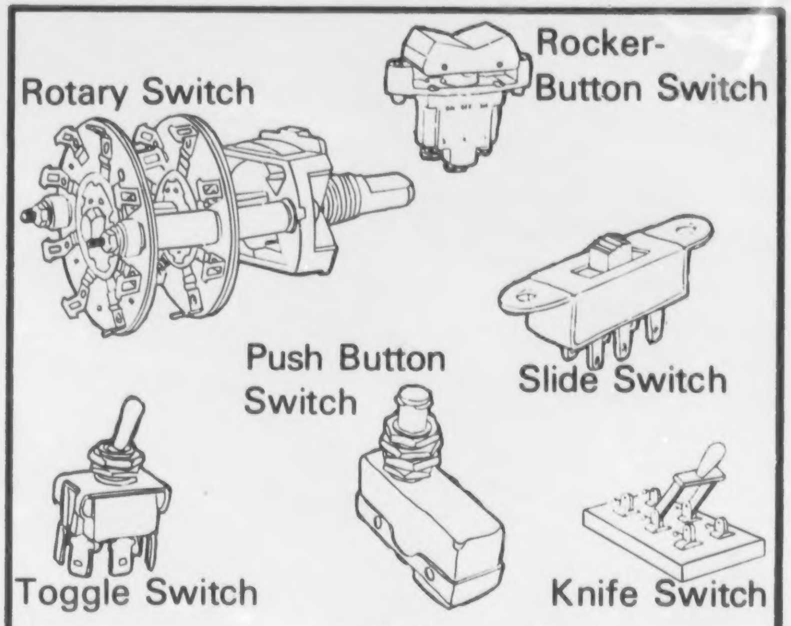
Fuses



Circuit Breaker

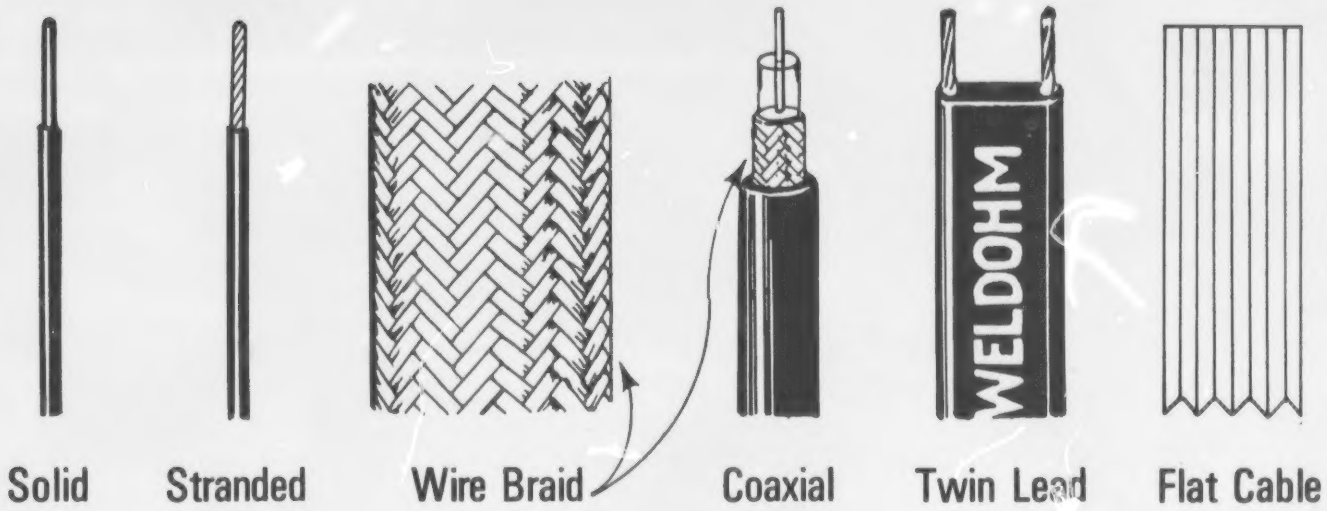

Sockets
Screw
Bayonet

Pilot Lamps

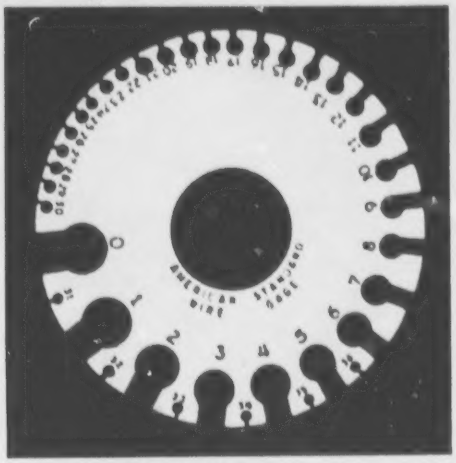

Rotary Switch
Rocker-
Button Switch
Push Button
Switch
Slide Switch
Toggle Switch
Knife Switch

Switches

Types of Wire Conductors


Solid
Stranded
Wire Braid
Coaxial
Twin Lead
WELDOHM
Flat Cable

Standard Copper Wire Gauge Sizes



AMERICAN STANDARD WIRE GAUGE
(ACTUAL SIZE)

GAUGE NO.	DIAMETER, MILS	CIRCULAR-MIL AREA	OHMS PER 1,000 FT OF COPPER WIRE AT 25°C*	GAUGE NO.	DIAMETER, MILS	CIRCULAR-MIL AREA	OHMS PER 1,000 FT OF COPPER WIRE AT 25°C*
1	289.3	83,690	0.1264	21	28.46	810.1	13.05
2	257.6	66,370	0.1593	22	25.35	642.4	16.46
3	229.4	52,640	0.2009	23	22.57	509.5	20.76
4	204.3	41,740	0.2533	24	20.10	404.0	26.17
5	181.9	33,100	0.3195	25	17.90	320.4	33.00
6	162.0	26,250	0.4028	26	15.94	254.1	41.62
7	144.3	20,820	0.5080	27	14.20	201.5	52.48
8	128.5	16,510	0.6405	28	12.64	159.8	66.17
9	114.4	13,090	0.8077	29	11.26	126.7	83.44
10	101.9	10,380	1.018	30	10.03	100.5	105.2
11	90.74	8,234	1.284	31	8.928	79.70	132.7
12	80.81	6,530	1.619	32	7.950	63.21	167.3
13	71.96	5,178	2.042	33	7.080	50.13	211.0
14	64.08	4,107	2.575	34	6.305	39.75	266.0
15	57.07	3,257	3.247	35	5.615	31.52	335.0
16	50.82	2,583	4.094	36	5.000	25.00	423.0
17	45.26	2,048	5.163	37	4.453	19.83	533.4
18	40.30	1,624	6.510	38	3.965	15.72	672.6
19	35.89	1,288	8.210	39	3.531	12.47	848.1
20	31.96	1,022	10.35	40	3.145	9.88	1,069

*20 to 25 C or 68 to 77 F is considered average room temperature.

Properties of Conducting Materials

MATERIAL	DESCRIPTION AND SYMBOL	p=SPECIFIC RESISTANCE, AT 20°C, CMIL Ω/FT	TEMPERATURE COEFFICIENT, PER °C, α	MELTING POINT °C
Aluminum	Element (Al)	17	0.004	660
Carbon	Element (C)	†	-0.0003	3000
Constantan	55% Cu, 45% Ni, alloy	295	0 (average)	1210
Copper	Element (Cu)	10.4	0.004	
Gold	Element (Au)	14	0.004	1063
Iron	Element (Fe)	58	0.006	1535
Manganin	84% Cu, 12% Mn, 4% Ni, alloy	270	0 (average)	910
Nichrome	65% Ni, 23% Fe, 12% Cr, alloy	676	0.0002	1350
Nickel	Element (Ni)	52	0.005	1452
Silver	Element (Ag)	9.8	0.004	961
Steel	99.5% Fe, 0.5% C, alloy	100	0.003	1480
Tungsten	Element (W)	33.8	0.005	3370

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* Listings approximate only, since precise values depend on exact composition of material.

† Carbon has about 2,500 to 7,500 times the resistance of copper. Graphite is a form of carbon.

CONDUCTORS AND INSULATORS
UNIT VIII

ASSIGNMENT SHEET #1–CALCULATE WIRE DIAMETERS, CROSS-SECTIONAL AREAS, AND RESISTANCE

1. The diameter of a copper wire is .040 inch.

    a. What is the circular mil area of the wire? ______________________________

    b. What is the AWG size? ______________________________

    c. What is the resistance of a 100-ft length? ______________________________

2. As the AWG number of wire increases,

    a. The diameter of the wire ____________________ (increases/decreases)

    b. The cross-sectional area of the wire ____________________ (increases/decreases)

    c. The resistance ________________ (increases/decreases)

    d. The voltage (IR) drop of the wire in a circuit ________________ (increases/decreases)

3. Circular mil ohm per foot (cmil-ohm/ft) represents: (check one)

    _____a. The breakdown voltage of an insulator

    _____b. The resistivity of a semiconductor

    _____c. The resistivity of a wire conductor

    _____d. The cross-sectional area of a wire conductor

4. The symbol ρ (Greek letter "rho") stands for (check one):

    _____a. the cross-sectional area of a conductor

    _____b. the resistivity of conducting material

    _____c. the breakdown voltage of a dielectric

    _____d. the temperature coefficient of conducting materials

ASSIGNMENT SHEET #1

5. The symbol α (Greek letter "alpha") stands for (check one):

   _____a. The temperature coefficient of conducting materials

   _____b. The specific resistance of conducting material

   _____c. The dielectric strength of insulators

   _____d. The resistivity of semiconductors

6. Calculate the total resistance (to nearest .1 ohm) of the following wires (at room temperature):

   a. 1000 ft of No. 14 copper wire R = __________

   b. 250 ft of No. 26 copper wire R = __________

   c. 511 ft of No. 20 copper wire R = __________

   d. 100 ft of aluminum wire with a diameter of .040 in. R = __________

   e. 1500 ft of silver wire with a diameter of .003 in. R = __________

7. A twin-lead cable of No. 20 copper wire is short-circuited at one end. The resistance reading at the open end is 2 ohms. What is the cable length in feet at room temperature? __________ft.

8. A coil is wound with 3000 turns of No. 18 copper wire. If the average amount of wire in a turn is 4 in.,

   a. How much is the total resistance of the wire? __________ohms

   b. What will be the resistance if No. 26 copper wire is used instead?

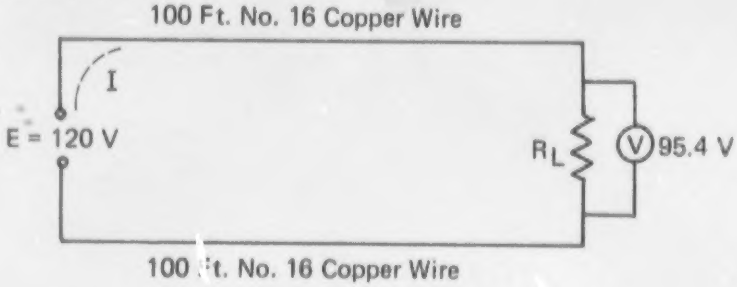
   __________ohms

9. If 200 ft of wire has to be used, what is the smallest size of copper wire that will limit the line drop of 5 V, with 120 V applied with a 6 A load? __________

10. Calculate the following for the circuit below:

    a. I = __________

    b. R_L = __________



CONDUCTORS AND INSULATORS
UNIT VIII

ANSWERS TO ASSIGNMENT SHEET #1

1. a. 1600 cmils
   b. No. 18
   c. 0.65 ohms
2. a. decreases
   b. decreases
   c. increases
   d. increases
3. c
4. b
5. a
6. a. 2.6 ohms
   b. 10.4 ohms
   c. 5.3 ohms
   d. 1.1 ohms
   e. 1633.3 ohms
7. 100 ft.
8. a. 6.51 ohms
   b. 41.62 ohms
9. No. 16 wire
10. a. 30 amps
    b. 3.18 ohms

CONDUCTORS AND INSULATORS
UNIT VIII

NAME______________________________

TEST

1. Match the terms on the right with their correct definitions.

_____a. One thousandth of an inch

_____b. A material of very high resistance which is capable of holding or storing an electrical charge

_____c. The capacity of a conducting rod of unit length and cross-sectional area to allow electrical current flow

_____d. The cross-sectional area of a wire calculated by squaring the wire diameter in mils

_____e. A material having relatively high resistance at room temperature, whose electrical characteristics can be changed and controlled by various techniques, such as by adding other elements called "impurities"

_____f. The electrical resistance of a rod of conducting material having a specified length and cross-sectional area

1. Resistivity or specific resistance
2. Conductivity
3. Semiconductor
4. Dielectric
5. Mil
6. Circular mil area

2. Distinguish between conductors, semiconductors, and insulators by placing "C" next to the conductors, an "S" next to the semiconductors, and an "I" next to the insulators.

_____a. Air or vacuum

_____b. Tungsten

_____c. Shellac

_____d. Silicon

_____e. Nickel

_____f. Rubber

_____g. Aluminum

_____h. Silver

_____i. Mica

_____j. Bakelite

_____k. Copper

_____l. Paper

_____m. Germanium

_____n. Iron

_____o. Glass

_____p. Gold

3. Describe four functional features of electrical conductors.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

4. Describe four functional features of electrical insulators.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

5. Name three major applications of conductors.

a. ______________________________

b. ______________________________

c. ______________________________

6. Name four types of wire conductors.

   a. ____________________

   b. ____________________

   c. ____________________

   d. ____________________

7. Select true statements about wire sizes and gauge numbers by placing an "X" in the appropriate blanks.

   _____a. The American Standard Wire Gauge is used to determine wire resistivity.

   _____b. The American Standard Wire Gauge is used to check wire sizes.

   _____c. "Circular mil" is the unit used to describe the diameter of a conducting wire.

   _____d. The cross-sectional area of a conducting wire is measured in square inches.

   _____e. The higher the gauge number of a wire, the lower its resistance.

   _____f. The higher the gauge number of a wire, the smaller its wire diameter.

(NOTE: Refer to the standard copper wire gauge table on the next page for the next four items.)

   _____g. The diameter of No. 19 copper wire is 35.89 mils.

   _____h. The diameter of No. 21 copper wire is 0.028 in.

   _____i. The cross-sectional area of No. 14 copper wire 64.08 cmils.

   _____j. The resistance of 100 feet of No. 26 copper wire is 4.2 ohms.

GAUGE	DIAMETER MILS	CIRCULAR-MIL AREA	OHMS PER 1,000 FT OF COPPER WIRE AT 25%C*	GAUGE NO.	DIAMETER MILS	CIRCULAR-MIL AREA	OHMS PER 1,000 FT OF COPPER WIRE NO. AT 25°C*
1	289.3	83,690	0.1264	21	28.46	810.1	13.05
2	257.6	66,370	0.1593	22	25.35	642.4	16.46
3	229.4	52,640	0.2009	23	22.57	509.5	20.76
4	204.3	41,740	0.2533	24	20.10	404.0	26.17
5	181.9	33,100	0.3195	25	17.90	320.4	33.00
6	162.0	26,250	0.4028	26	15.94	254.1	41.62
7	144.3	20,820	0.5080	27	14.20	201.5	52.48
8	128.5	16,510	0.6405	28	12.64	159.8	66.17
9	114.4	13,090	0.8077	29	11.26	126.7	83.44
10	101.9	10,380	1.018	30	10.03	100.5	105.2
11	90.74	8,234	1.284	31	8.928	79.70	132.7
12	80.81	6,530	1.619	32	7.950	63.21	167.3
13	71.96	5,178	2.042	33	7.080	50.13	211.0
14	64.08	4,107	2.575	34	6.305	39.75	266.0
15	57.07	3,257	3.247	35	5.615	31.52	335.0
16	50.82	2,583	4.094	36	5.000	25.00	423.0
17	45.26	2,048	5.163	37	4.453	19.83	533.4
18	40.30	1,624	6.510	38	3.965	15.72	672.6
19	35.89	1,288	8.210	39	3.531	12.47	848.1
20	31.96	1,022	10.35	40	3.145	9.88	1,069.

*20 to 25°C or 68 to 77°F is considered average room temperature.

8. Select true statements about the properties of conducting materials by placing an "X" in the appropriate blanks.

_____a. Specific resistance and resistivity refer to the same property.

_____b. The symbol for resistivity is the Greek letter "alpha" (α).

_____c. Resistivity of wire conductors is expressed in mm^2-ohms per foot.

_____d. If a conducting material has a positive temperature coefficient, its resistivity increases with temperature.

_____e. The resistivity of conducting materials does not change with temperature.

_____f. Cmil-ohms/foot is the expression for resistivity.

9. Select the true statements regarding wire resistance by placing an "X" in the appropriate blanks.

_____a. The thicker the wire, the higher its resistance.

_____b. The longer the wire, the higher its resistance.

_____c. If the resistivity of silver is 9.8 cmil-ohms per foot, the total resistance of a 100-ft length of silver wire having a diameter of 0.003 in. is 1089 ohms.

_____d. If the resistivity of aluminum is 17 cmil-ohms per foot, the total resistance of a 200-ft length of aluminum wire having a diameter of 0.01 in. is 20 ohms.

_____e. If the resistivity of steel is 100 cmil-ohms per foot, the total resistance of a 10-ft length of steel wire having a cross-sectional area of 50 cmils is 2 ohms.

10. Name three desirable properties of wire insulation.

a. ____

b. ____

c. ____

11. Calculate diameters, cross-sectional areas, and resistance.

(NOTE: If this activity has not been accomplished prior to the test, ask your instructor when it should be completed.)

CONDUCTORS AND INSULATORS
UNIT VIII

ANSWERS TO TEST

1.

a.	5	d.	6
b.	4	e.	3
c.	2	f.	1

2.

a.	I	f.	I	k.	C	p.	C
b.	C	g.	C	l.	I		
c.	I	h.	C	m.	S		
d.	S	i.	I	n.	C		
e.	C	j.	I	o.	I		

3. Description should include:

   a. Many free electrons
   b. Low resistance to electrical current
   c. Little voltage drop
   d. Low power dissipation

4. Description should include:

   a. Few free electrons
   b. High resistance to electrical current
   c. Hold or store an electrical charge
   d. High dielectric strength

5. Any three of the following:

   a. Wiring
   b. Switches
   c. Pilot lamp filaments
   d. Fuses and circuit breakers

6. Any four of the following:

   a. Solid
   b. Stranded
   c. Wire braid
   d. Coaxial cable
   e. Twin-lead cable
   f. Flat cable

7. b, f, g, h, j

8. a, d, f

9. b, c, e

10. Any three of the following:

    a. High resistance
    b. Toughness
    c. Flexibility
    d. Nonbrittleness with aging

11. Evaluated to the satisfaction of the instructor.

OHM'S LAW
UNIT IX

UNIT OBJECTIVE

After completion of this unit, the student should be able to state Ohm's law and use Ohm's law to solve problems. The student should also be able to use Ohm's law with circuit measurements. This knowledge will be evidenced by correctly performing the procedures outlined in the assignment and job sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match the terms on the right with the correct definitions.
2. Match letter designations used in Ohm's law with the correct terms.
3. State Ohm's law.
4. Draw the circular expression of Ohm's law.
5. List three uses of Ohm's law.
6. Solve problems for an unknown voltage.
7. Solve problems for an unknown current.
8. Solve problems for an unknown resistance.
9. Demonstrate the ability to use Ohm's law with circuit measurements.

OHM'S LAW
UNIT IX

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information, assignment, and job sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information and assignment sheets.

VI. Demonstrate and discuss the procedures outlined in the job sheet.

VII. Give students additional problems when working with Ohm's law.

VIII. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:
   A. Objective sheet
   B. Information sheet
   C. Transparency masters
      1. TM 1--Ohm's Law
      2. TM 2--Ohm's Law Magic Circle
      3. TM 3--Ohm's Law--Computing Resistance
      4. TM 4--Ohm's Law--Computing Current
      5. TM 5--Ohm's Law--Computing Voltage
   D. Assignment sheets
      1. Assignment Sheet #1--Solve Problems for an Unknown Voltage
      2. Assignment Sheet #2--Solve Problems for an Unknown Amperage
      3. Assignment Sheet #3--Solve Problems for an Unknown Resistance

- E. Answers to assignment sheets
- F. Job Sheet #1--Use Ohm's Law with Circuit Measurements
- G. Test
- H. Answers to test

II. References:

- A. Grob, Bernard. *Basic Electronics.* New York: McGraw-Hill, 1977.
- B. *The Radio Amateur's Handbook*. Newington, CT: ARRL, 1978.

OHM'S LAW
UNIT IX

INFORMATION SHEET

I. Terms and definitions

   A. Volt--Unit of measure of electromotive force or potential difference

   B. Ohm--Unit of measure for the opposition to electron flow in a circuit

   C. Ampere--Unit of measure for the intensity of electron flow (current) in a circuit

   D. Watt--Unit of measure for power

   E. Direct proportion--A situation where one variable moves in the same direction as another variable when other conditions remain constant

      Example: Current doubles as voltage is doubled when resistance is held constant; thus, voltage and current are directly proportional

   F. Inverse proportion--A situation where one variable moves in the opposite direction from another variable when other conditions remain constant

      Example: With a constant voltage, current increases when resistance decreases; thus, current and resistance are inversely proportional

   G. Amperage--Level of current flow

II. Letters and terms used in Ohm's law

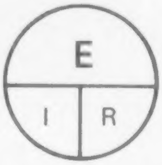
   A. E--Electromotive force (emf) in volts

   B. I--Electrical current in amperes

   C. R--Resistance in ohms

III. Ohm's law--The current (amperes) in an electric circuit equals the electromotive force or potential (volts) divided by the resistance (ohms) (Transparency 1)

IV. Ohm's law in circular expression (Transparency 2)



INFORMATION SHEET

V. Uses of Ohm's law

A. Calculating circuit resistance (Transparency 3)

Example: $R = \frac{E}{I}$

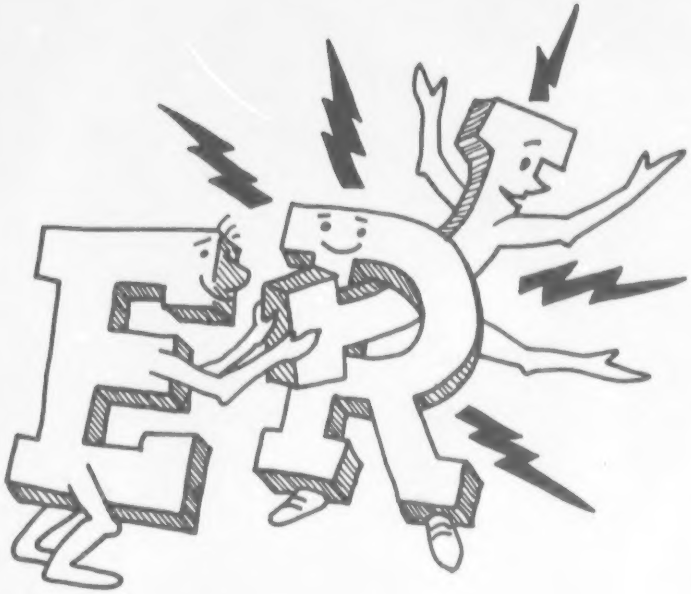
B. Calculating circuit amperage (Transparency 4)

Example: $I = \frac{E}{R}$

C. Calculating circuit voltage (Transparency 5)

Example: $E = IR$

Ohm's Law



One volt is required to push one amp through one ohm resistance.

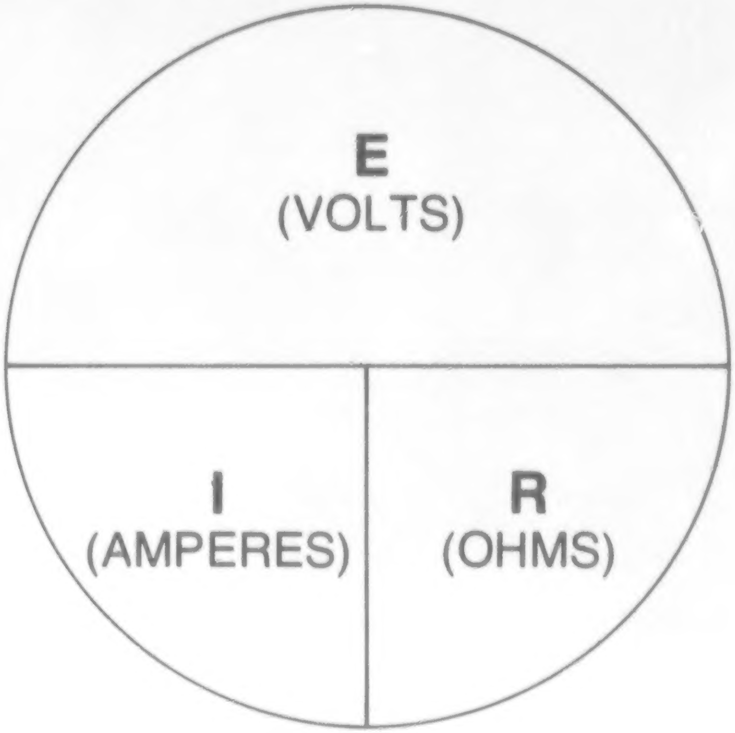
$$E = IR$$

Volts = Amperes x Ohms

TM 1

BE - 299-C

Ohm's Law Magic Circle



E
(VOLTS)

I
(AMPERES)

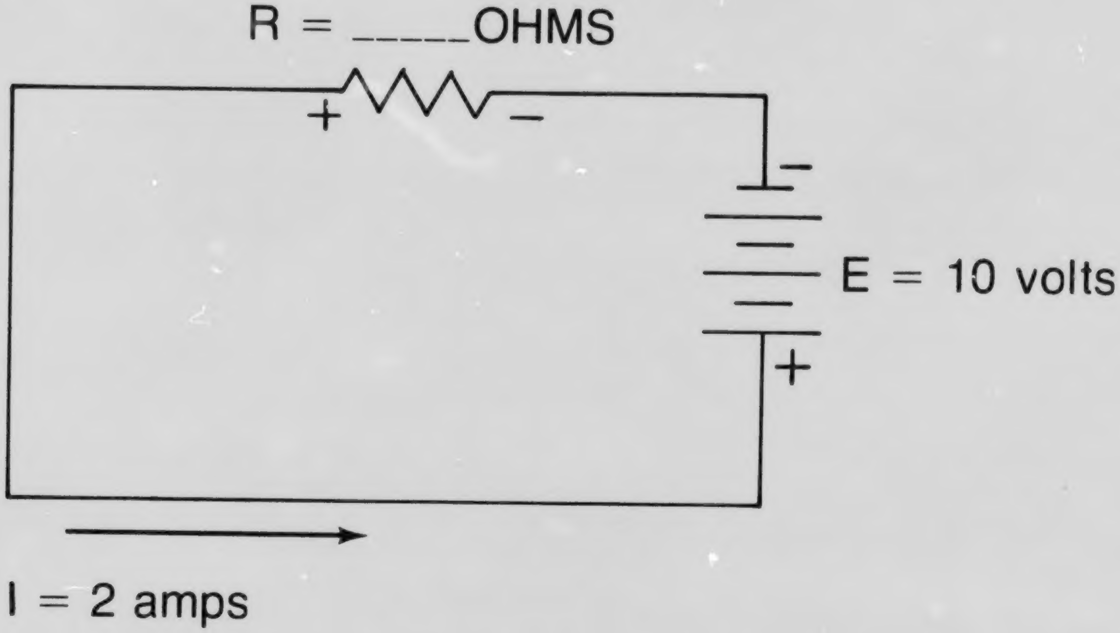
R
(OHMS)

$E = IR$

$I = \frac{E}{R}$

$R = \frac{E}{I}$

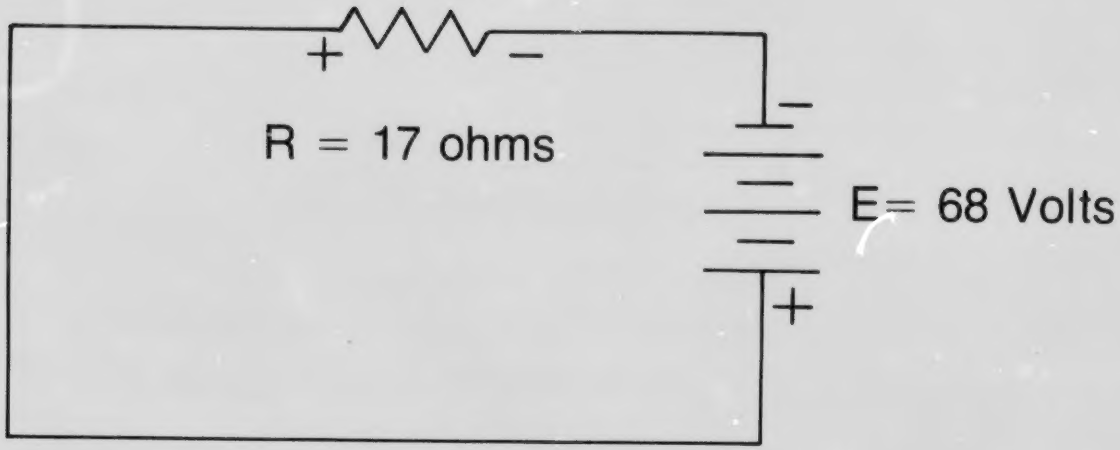
Ohm's Law--Computing Resistance


R = _____OHMS
+
−
−
E = 10 volts
+
I = 2 amps

What is the resistance value of the resistor in this circuit?

$E = IR$ $\qquad R = \frac{E}{I}$ $\qquad R = \frac{10 \text{ volts}}{2 \text{ amperes}} = 5 \text{ ohms}$

Ohm's Law--Computing Current

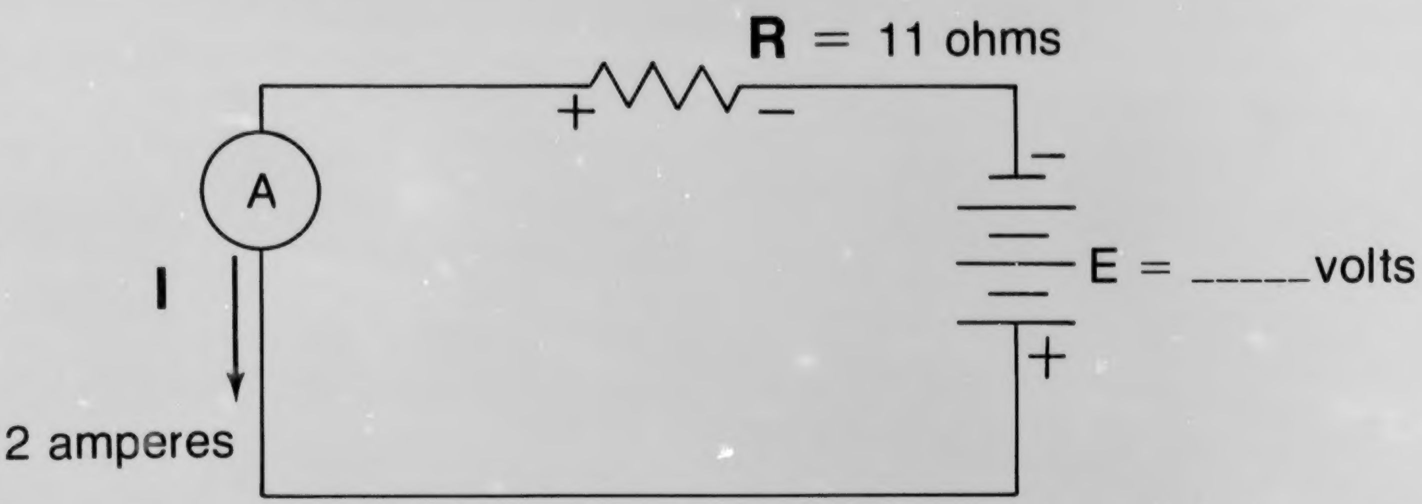


I = _____ amps

How many amperes of current are flowing in this circuit?

$E = IR$ $\qquad I = \frac{E}{R}$ $\qquad I = \frac{68 \text{ volts}}{17 \text{ ohms}} = 4 \text{ amperes}$

Ohm's Law--Computing Voltage


R = 11 ohms
+
−
A
I
2 amperes
−
+
E = _____volts

What voltage is being supplied by the battery?

E = IR E = 2 amperes x 11 ohms, E = 22 volts

The value of the voltage being supplied by the battery is 22.

OHM'S LAW
UNIT IX

ASSIGNMENT SHEET #1--SOLVE PROBLEMS FOR AN UNKNOWN VOLTAGE

Directions: Apply the appropriate formula from Ohm's law to find the voltage in the following problems.

Example: 2 amps, 60 ohms = _____ volts

Answer: E = IR = 2 x 60 = 120 volts

Problems:

	Amps	Ohms	Volts
1.	20	6	____
2.	4	60	____
3.	9.6	2.5	____
4.	5	3	____
5.	75	0.16	____
6.	2×10^{-3}	5×10^{3}	____
7.	1×10^{-6}	10×10^{3}	____
8.	8μ	1M	____
9.	2m	2K	____
10.	1	1	____

OHM'S LAW
UNIT IX

ASSIGNMENT SHEET #2--SOLVE PROBLEMS FOR AN UNKNOWN AMPERAGE

Directions: Apply the appropriate formula to find the amperage in the following problems.

Example: 120 volts, 40 ohms = _____ amps

Answer: I = E/R = 120/40 = 3 amps

Problems:

	Volts	Ohms	Amps
1.	240	12	___
2.	110	11	___
3.	440	20	___
4.	120	30	___
5.	24	3	___
6.	12	1	___
7.	5×10^{-6}	1	___
8.	2×10^{-3}	4×10^{-3}	___
9.	20 KV	$5 \times 10^{+6}$	___
10.	1 KV	0.5×10^{6}	___

OHM'S LAW
UNIT IX

ASSIGNMENT SHEET #3--SOLVE PROBLEMS FOR AN UNKNOWN RESISTANCE

Directions: Apply the appropriate formula to find resistance.

Example: 440 volts, 10 amps = ______ ohms

Answer: R = E/I = 440/10 = 44 ohms

Problems:

	Volts	Amps	Ohms
1.	240	4	____
2.	24	9.6	____
3.	12	5	____
4.	230	5	____
5.	24	8	____
6.	24	2 mA	____
7.	12	3 μA	____
8.	1 KV	5 mA	____
9.	1×10^3	0.5×10^{-3}	____
10.	2.5×10^3	5×10^{-3}	____

OHM'S LAW
UNIT IX

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

1. 120V
2. 240V
3. 24V
4. 15V
5. 12V
6. 10V
7. 0.01 or 10^{-2}V
8. 8V
9. 4V
10. 1V

Assignment Sheet #2

1. 20A
2. 10A
3. 22A
4. 4A
5. 8A
6. 12A
7. 5×10^{-6} or 0.000005 or 5 μA
8. 500×10^{-3} or 0.5 or 5mA
9. 4×10^{-3} or 0.004 4mA
10. 2×10^{-3} or 0.002 or 2mA

Assignment Sheet #3

1. 60 Ω
2. 2.5 Ω
3. 2.4 Ω
4. 46 Ω
5. 3 Ω
6. 12K or 12,000 Ω
7. 4M or 4,000,000 Ω
8. 200K or 200,000 Ω
9. 2×10^{6} or 2,000,000 Ω
10. 500K or 500,000 Ω

OHM'S LAW
UNIT IX

JOB SHEET #1--USE OHM'S LAW WITH CIRCUIT MEASUREMENTS

I. Tools and materials

A. Power supply, 0-6V DC or equivalent

B. One 3.3-Kohm resistor and one [illegible]-Kohm resistor

C. Multimeter (or ammeter and voltmeter)

D. Switch, SPST

II. Procedure

A. Connect the DC power supply to one 3.3 Kohm resistor in series with an ammeter (Figure 1)

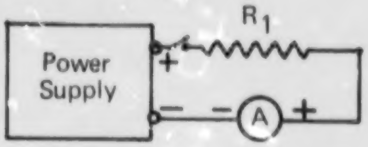


FIGURE 1

B. Turn on the power supply and adjust for a 3 volt output

C. Close the switch, then read and record the ammeter indication in the data table (Table 1)

	OBSERVED			COMPUTED		
DATA TABLE	E	I	R	E	I	R
Step C	3V	___	3.3K	___	___	___
Step E	6V	___	3.3K	___	___	___
Step I	3V	___	4.3K	___	___	___
Step L	___	___	3.3K	___	___	___
Step M	___	___	3.3K	___	___	___
Step N	___	___	3.3K	___	___	___

JOB SHEET #1

D. Increase the output of the power supply to 6 volts

E. Read the ammeter indication and record in the data table

F. Compare the current observed in Step C with that observed in Step E

(NOTE: With no change in resistance, an increase in voltage results in (increase) (decrease) of circuit current.)

G. Turn off the power supply and install both resistors in series with the ammeter (Figure 2)

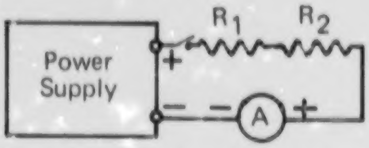


FIGURE 2

H. Turn on the power supply and adjust for a 3 volt output

I. Read the ammeter indication and record in the data table

J. Compare the current observed in Step I with that observed in Step C

(NOTE: With no change in voltage, does an increase in resistance result in an increase or decrease of circuit current?)

K. Connect a voltmeter across the 3.3 Kohm resistor

L. Read the voltmeter indication and record in the data table

M. Observe the ammeter indication and adjust the power supply for a slight increase in the circuit current

N. Read the voltmeter indication and record in the data table

O. Compare the voltage observed in Step L with that observed in Step N

(NOTE: With no change in resistance, does an increase in current result in increase or decrease of voltage?)

P. Use the observed values for E, I, and R and compute these values using Ohm's law

Q. Record your results in the spaces provided in the data table

OHM'S LAW
UNIT IX

NAME ______________________________

TEST

1. Match the terms on the right to the correct definition.

_____a. Unit of measure of electromotive force or potential difference

_____b. Unit of measure for the opposition to electron flow in a circuit

_____c. Unit of measure for the intensity of electron flow in a circuit

_____d. Unit of measure for power

_____e. A situation where one variable moves in the same direction as another variable when other conditions remain constant

_____f. A situation where one variable moves in the opposite direction from another variable when other conditions remain constant

_____g. Level of current flow

1. Ampere
2. Watt
3. Volt
4. Ohm
5. Inverse proportion
6. Direct proportion
7. Amperage

2. Match the letter designations on the right with the correct terms.

_____a. Electromotive force in volts

_____b. Electrical current in amperes

_____c. Resistance in ohms

1. R
2. E
3. I

3. State Ohm's law.

4. Draw the circular expression of Ohm's law.

5. List three uses of Ohm's law.

   a. ______________________________

   b. ______________________________

   c. ______________________________

6. Solve for unknown voltage when I = 2 milliamps and R = 3 kilo-ohms

   E = ____________________

7. Solve for unknown current when E = 12 volts and R = 12 ohms

   I = ____________________

8. Solve for unknown resistance when E = 110 volts and I = 2 amperes

   R = ____________________

9. Demonstrate the ability to use Ohm's law with circuit measurements.

   (NOTE: If this activity has not been accomplished prior to the test, ask your instructor when it should be completed.)

OHM'S LAW
UNIT IX

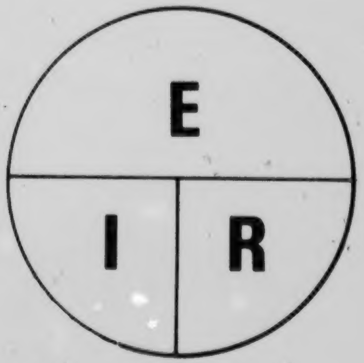
ANSWERS TO TEST

1. a. 3
   b. 4
   c. 1
   d. 2
   e. 6
   f. 5
   g. 7

2. a. 2
   b. 3
   c. 1

3. The current in an electric circuit equals the electromotive force or potential divided by the resistance

4.



5. a. Calculating circuit resistance
   b. Calculating circuit amperage
   c. Calculating circuit voltage

6. 6 volts

7. 1 ampere

8. 55 ohms

9. Performance skill evaluated to the satisfaction of the instructor

SERIES CIRCUITS
UNIT X

UNIT OBJECTIVE

After completion of this unit, the student should be able to determine total voltage, voltage drops across resistances, and the total resistance in a series circuit. The student should also be able to measure voltage drops and analyze current values, resistance, and power in a series circuit. This knowledge will be evidenced by correctly performing the procedures outlined in the assignment and job sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms associated with series circuits with their correct definitions.
2. Match abbreviations or symbols with their correct definitions.
3. Select true statements concerning rules for series circuits.
4. Distinguish between a direct and partial short circuit.
5. Determine total voltage in a series circuit.
6. Determine voltage drops across resistances.
7. Determine total resistance in a series circuit.
8. Determine current in a series circuit.
9. Determine one unknown circuit value in a series circuit.
10. Determine several unknown values in resistive series circuits.
11. Compute the power dissipated in a resistive series circuit.
12. Demonstrate the ability to:
    a. Measure voltage drops in a series circuit.
    b. Analyze current values in a series circuit.
    c. Analyze resistance and power in a series circuit.

SERIES CIRCUITS
UNIT X

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information, assignment, and job sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information and assignment sheets.

VI. Demonstrate and discuss the procedures outlined in the job sheets.

VII. Mask out color codes and let students determine standard resistor values.

VIII. Practice connecting resistors in series.

IX. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

   A. Objective sheet

   B. Information sheet

   C. Transparency masters

      1. TM 1--Memory Wheel for Solving Problems

      2. TM 2--Simple Series Circuit

      3. TM 3--Combined Series Circuit

   D. Assignment sheets

      1. Assignment Sheet #1--Determine Total Voltage in a Series Circuit

      2. Assignment Sheet #2--Determine Voltage Drops Across Resistances

      3. Assignment Sheet #3--Determine the Total Resistance in a Series Circuit

      4. Assignment Sheet #4--Determine Current in a Series Circuit

      5. Assignment Sheet #5--Determine Unknown Circuit Values

6. Assignment Sheet #6--Determine Unknown Values in a Resistive Series Circuit

7. Assignment Sheet #7--Compute the Power Dissipated in a Resistive Series Circuit

E. Answers to assignment sheets

F. Job sheets

1. Job Sheet #1--Measure Voltage Drops in a Series Circuit

2. Job Sheet #2--Analyze Current Values in a Series Circuit

3. Job Sheet #3--Analyze Resistance and Power in a Series Circuit

G. Test

H. Answers to test

II. References:

A. *Radio Amateur's Handbook.* Newington, CT: ARRL, 1978.

B. Grob, Bernard. *Basic Electronics.* New York: McGraw-Hill, 1977.

C. *IEEE Standard Dictionary of Electrical and Electronic Terms.* New York: John Wiley and Sons, 1972.

SERIES CIRCUITS
UNIT X

INFORMATION SHEET

I. Terms and definitions

A. Series circuit--A circuit where the same current passes through each component

B. Short circuit--An abnormal connection of relatively low resistance between two points of differing potential in a circuit

C. Fuse--An overcurrent protective device with an element that melts and opens the circuit when overheated

D. Open circuit--A circuit with no available path for current flow (infinitive resistance)

E. Circuit--A system of conductors through which an electric current is intended to flow

F. Circuit breaker--A device designed to switch open a circuit automatically when a current overload exists

G. Voltage drop--The difference of voltages at two terminals of a component having opposition to current flow

H. Applied voltage--The sum of the series IR drops (Kirchhoff's Law)

I. IR drop--Voltage derived from Ohm's law

II. Abbreviations or symbols and definitions (Transparency 1)

A. I_T -- Total current

B. E_T -- Total voltage

(NOTE: E_A also equals the total or applied voltage.)

C. R_T -- Total resistance

D. P_T -- Total power dissipated

E. R_1 -- Resistor number 1

(NOTE: Resistor number 2 is R_2, and this method of numbering continues for other resistors.)

F. V_1 -- Voltage across R_1 which equals IR_1

(NOTE: E can be used instead of V for voltage, eg. E_1. Other resistors are numbered in this same manner.)

SERIES CIRCUITS
UNIT X

INFORMATION SHEET

G. P_1--Power dissipated by resistor R_1

(NOTE: This method of numbering is the same for P_2, P_3, etc.)

H. P_{R1}--Power dissipated by resistor R_1

(NOTE: This method of numbering is the same for R_2, R_3, etc.)

I. V_{R1}--Voltage across R_1

(NOTE: This method of numbering is the same for R_2, R_3, etc.)

III. Rules for series circuits (Transparencies 2 and 3)

A. Applied voltage

1. Sum of the voltage drops equals the applied voltage

(NOTE: This is Kirchhoff's Law.)

2. Voltage drops are additive

B. Largest voltage drop is across the component with the most resistance

C. Resistance

1. Sum of resistances equals the total resistance

2. Resistance is additive

D. Current is same through all components

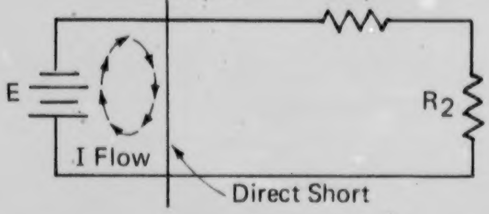
(NOTE: At every point in a circuit Ohm's law is true.)

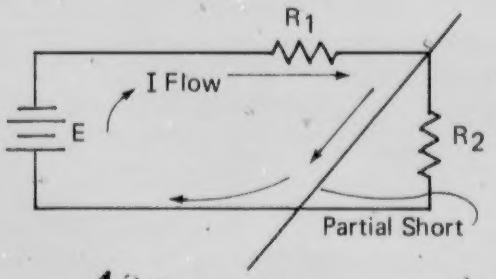
IV. Short circuits

A. Direct short

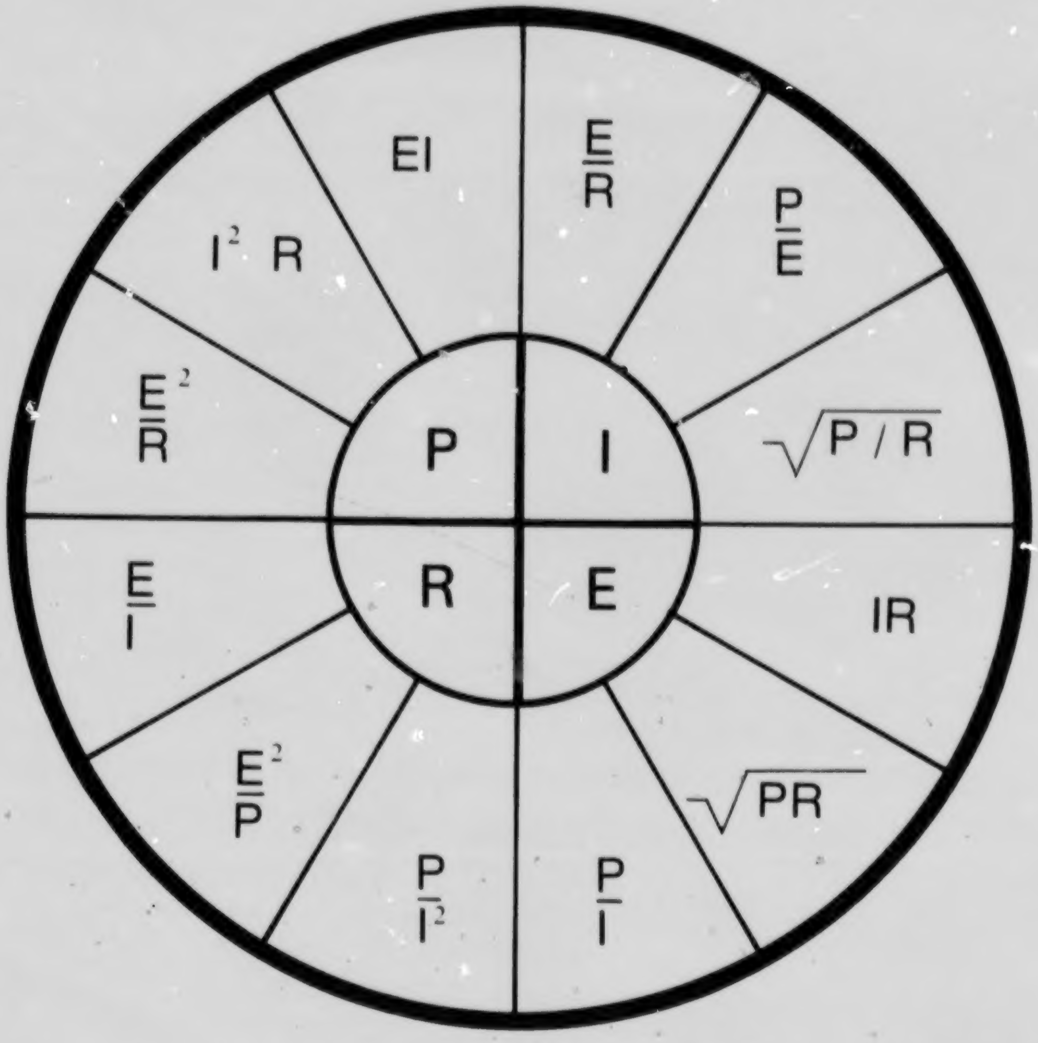
B. Partial short

Example:





Memory Wheel for Solving Problems



P

EI

$I^2 R$

$\frac{E^2}{R}$

I

$\frac{E}{R}$

$\frac{P}{E}$

$\sqrt{P/R}$

E

IR

$\sqrt{PR}$

$\frac{P}{I}$

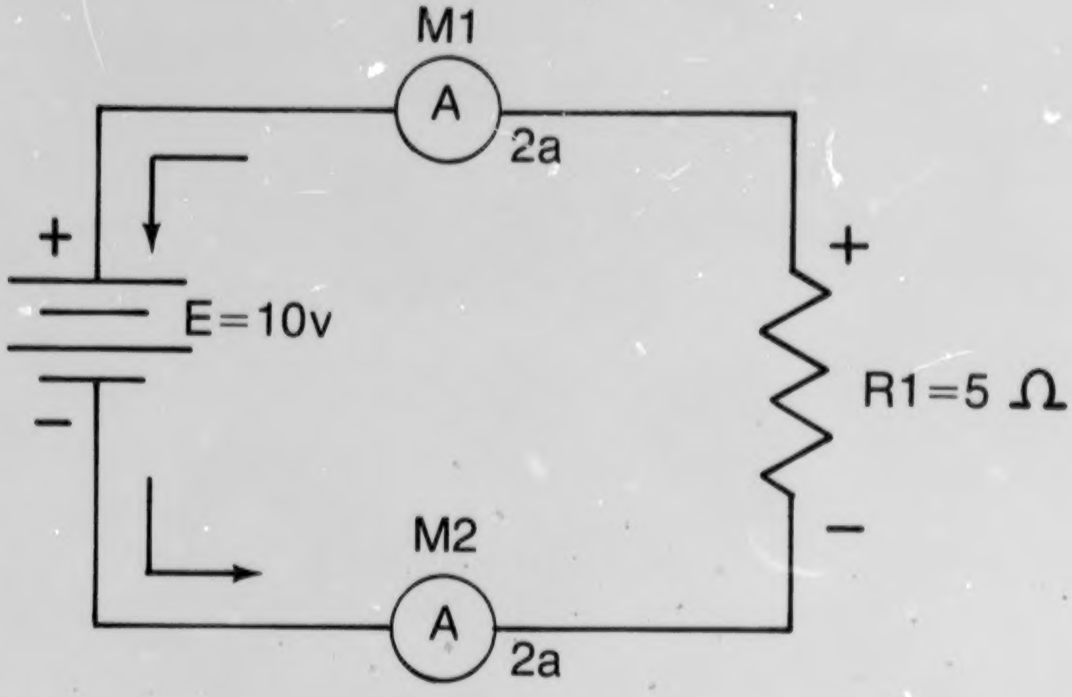
R

$\frac{P}{I^2}$

$\frac{E^2}{P}$

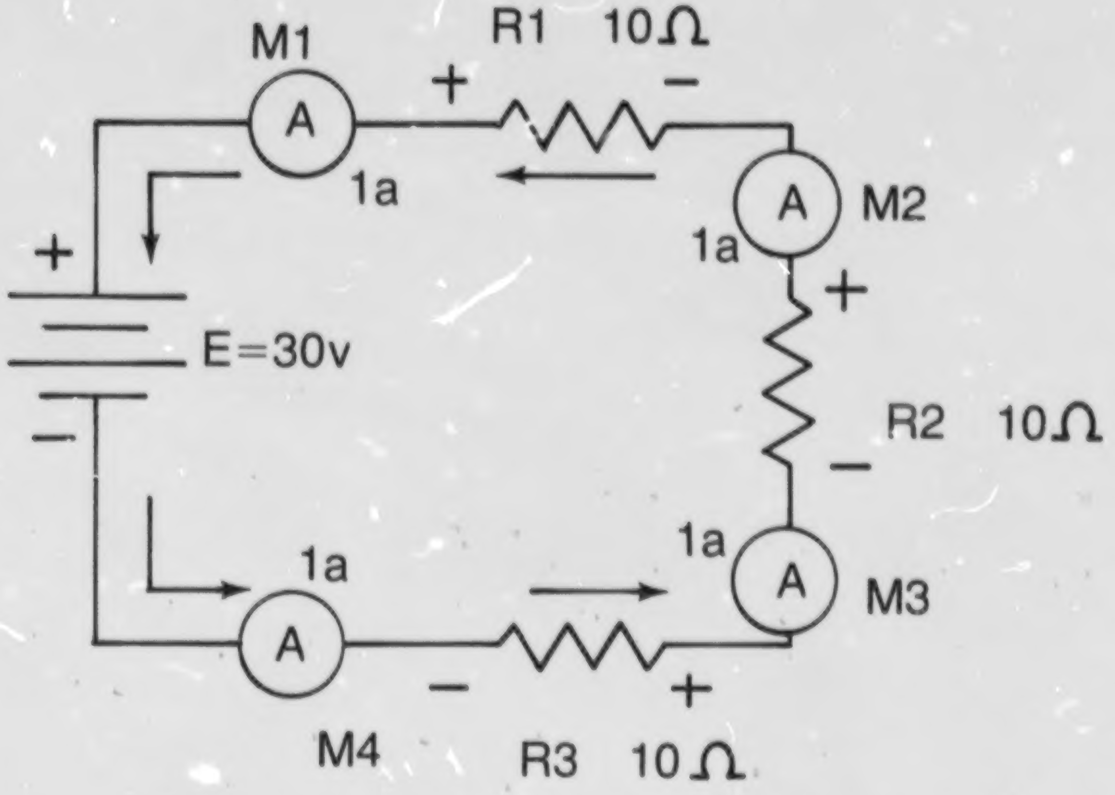
$\frac{E}{I}$

Simple Series Circuit


M1
A
2a
+
E=10v
–
+
R1=5 Ω
–
M2
A
2a

Current measured by M1 will equal that of M2.

Combined Series Circuit

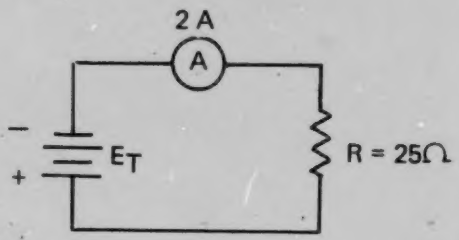

M1
R1 10Ω
+
−
A
1a
A
M2
1a
+
E=30v
+
−
R2 10Ω
−
1a
A
M3
1a
A
−
+
M4
R3 10Ω

Current measured by M1 will equal that of M2, M3 or M4.

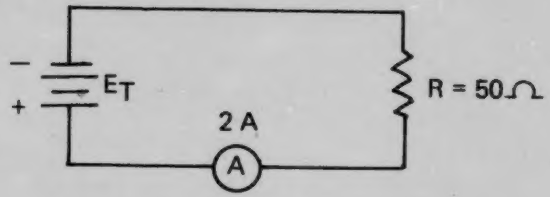
SERIES CIRCUITS
UNIT X

ASSIGNMENT SHEET #1--DETERMINE TOTAL VOLTAGE IN A SERIES CIRCUIT

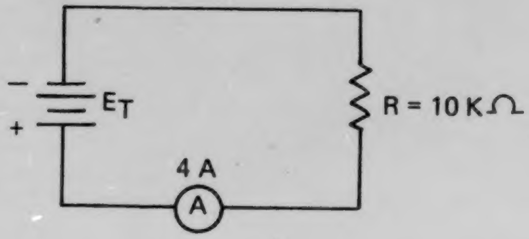
1. E_T = ________



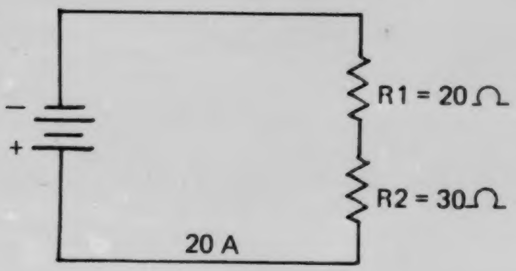
2. E_T = ________



3. E_T = ________

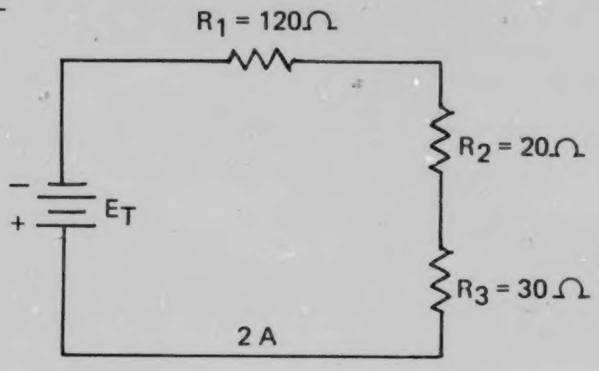

–
+
E_T
R = 10 KΩ
4 A
A

4. E_T = ________


–
+
R1 = 20Ω
R2 = 30Ω
20 A

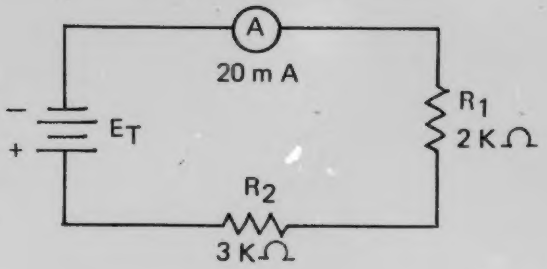
ASSIGNMENT SHEET #1

5. E_T = ________



R1 = 120Ω
R2 = 20Ω
R3 = 30Ω
–
+
ET
2 A

6. E_T = ________



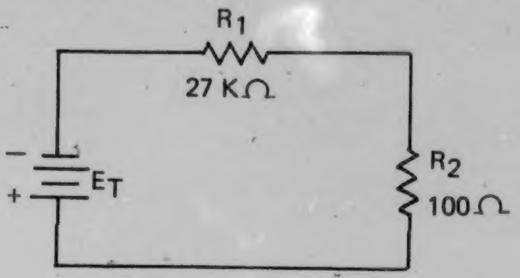
A
20 m A
–
+
ET
R1
2 KΩ
R2
3 KΩ

SERIES CIRCUITS
UNIT X

ASSIGNMENT SHEET #2--DETERMINE VOLTAGE DROPS ACROSS RESISTANCES

1. True or False?

______ V_{R1} is greater than V_{R2}

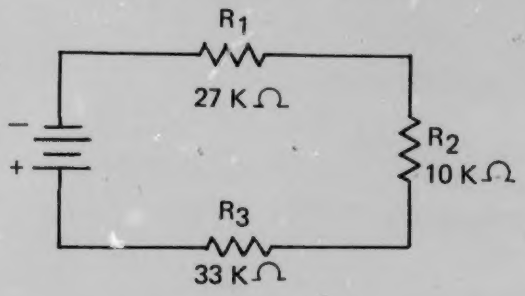

R_1
27 KΩ
R_2
100Ω
E_T
−
+

2. The largest voltage drop is

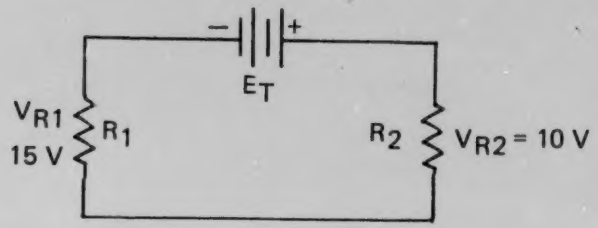
______ a. V_{R1}

______ b. V_{R2}

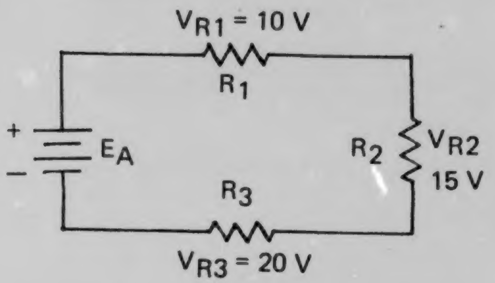
______ c. V_{R3}


R_1
27 KΩ
R_2
10 KΩ
R_3
33 KΩ
−
+

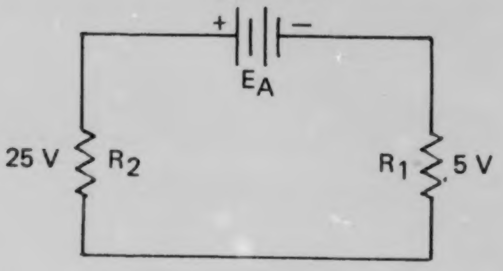
3. E_T = ______


−
+
E_T
V_{R1}
15 V
R_1
R_2
V_{R2} = 10 V

4. E_A = ______


V_{R1} = 10 V
R_1
+
−
E_A
R_2
V_{R2}
15 V
R_3
V_{R3} = 20 V

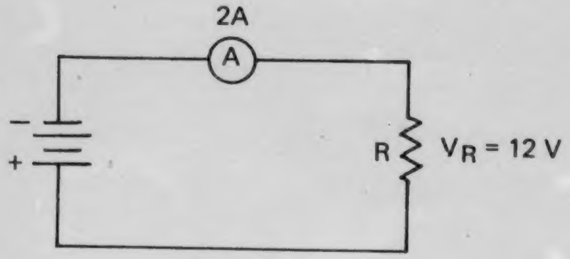
5. E_A = ______


+
−
E_A
25 V
R_2
R_1
5 V

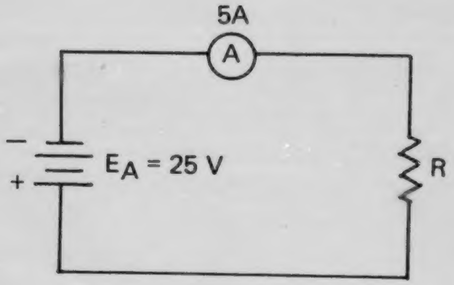
SERIES CIRCUITS
UNIT X

ASSIGNMENT SHEET #3--DETERMINE THE TOTAL RESISTANCE IN A SERIES CIRCUIT

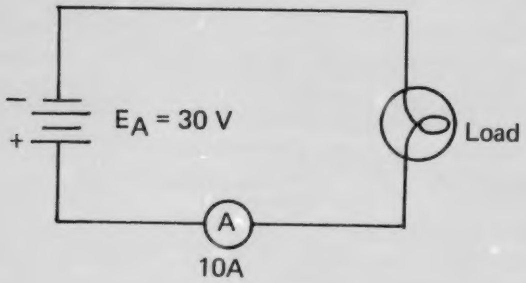
1. R_T = _____



2. R_T = _____



3. R_T = _____

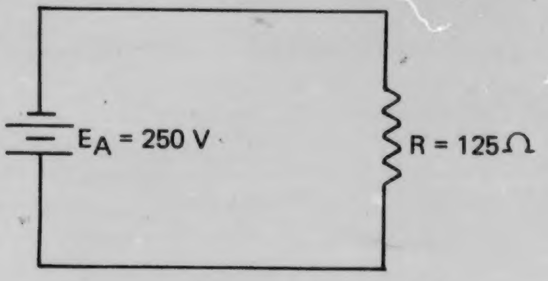

−
+
E_A = 30 V
Load
A
10A

SERIES CIRCUITS
UNIT X

ASSIGNMENT SHEET #4--DETERMINE CURRENT IN A SERIES CIRCUIT

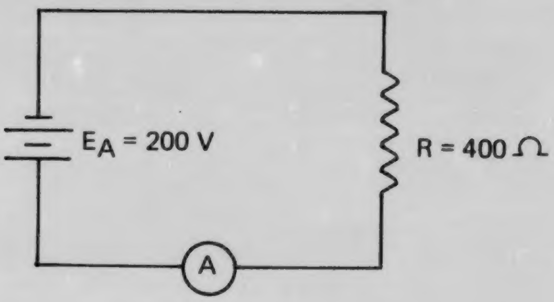
Directions: Determine the current in the following series circuits. Be sure to indicate units.

1. I = _____



E_A = 250 V
R = 125Ω

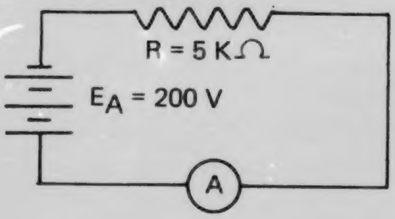
2. I = _____



E_A = 200 V
R = 400Ω
A

3. I = _____

(NOTE: Give answer in milliamperes.)

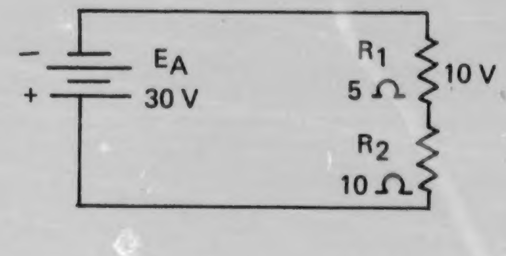


R = 5 KΩ
E_A = 200 V
A

SERIES CIRCUIT
UNIT X

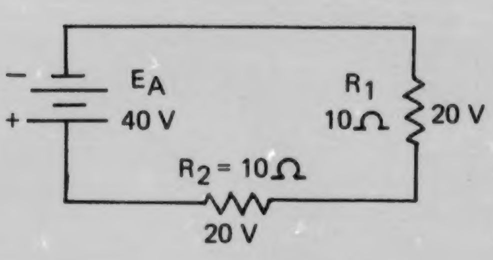
ASSIGNMENT SHEET #5--DETERMINE UNKNOWN CIRCUIT VALUES

1. I_{R1} = _____



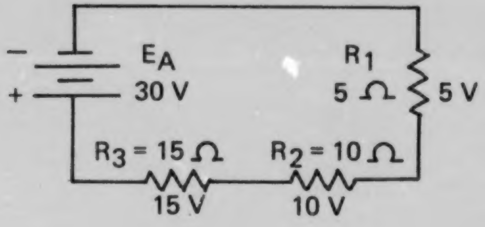
−
+
E_A
30 V
R_1
5 Ω
10 V
R_2
10 Ω

2. I_{R2} = _____



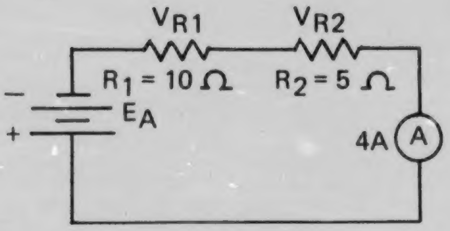
−
+
E_A
40 V
R_1
10 Ω
20 V
R_2 = 10 Ω
20 V

3. I_{R3} = _____



−
+
E_A
30 V
R_1
5 Ω
5 V
R_3 = 15 Ω
15 V
R_2 = 10 Ω
10 V

4. V_{R2} = _____

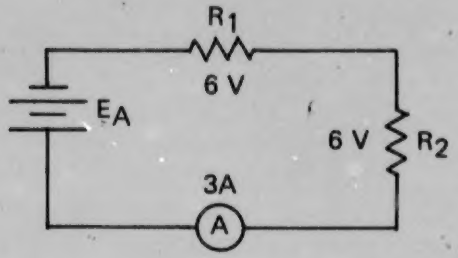


V_{R1}
V_{R2}
R_1 = 10 Ω
R_2 = 5 Ω
−
+
E_A
4A
A

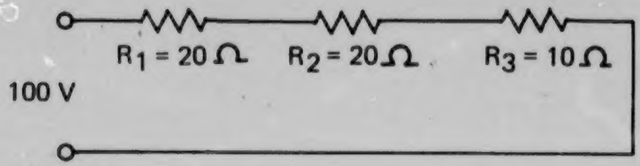
(NOTE: The Ohm's law formula applies to all parts of a circuit.)

ASSIGNMENT SHEET #5

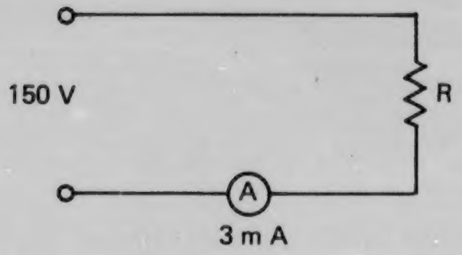
5. R2 = ______


R_1
6 V
E_A
6 V
R_2
3A
A

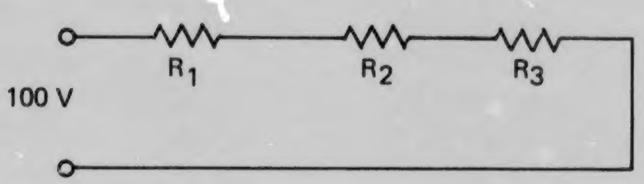
6. V_3 = ______


$R_1 = 20\,\Omega$
$R_2 = 20\,\Omega$
$R_3 = 10\,\Omega$
100 V

7. R = ______



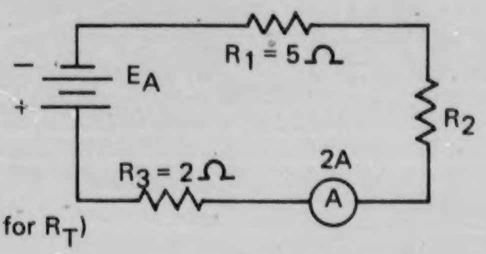
8. V_1 = ______


R_1
R_2
R_3
100 V

SERIES CIRCUITS
UNIT X

ASSIGNMENT SHEET #6--DETERMINE UNKNOWN VALUES IN A RESISTIVE SERIES CIRCUIT

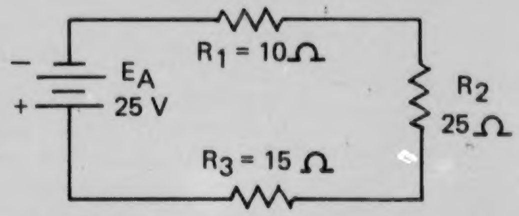
1. R2 = ______



E_A
$R_1 = 5\,\Omega$
R_2
$R_3 = 2\,\Omega$
2A
A
−
+

(NOTE: First solve for R_T)

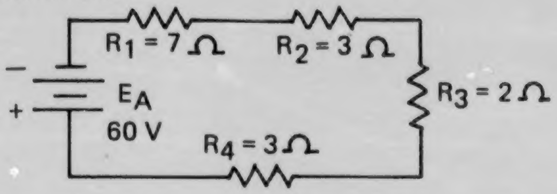
2. V_{R1} = ______



E_A
25 V
$R_1 = 10\,\Omega$
R_2
$25\,\Omega$
$R_3 = 15\,\Omega$
−
+

(NOTE: To solve for any one part of a circuit, you must have two known values of that part. If solving for volts, you must first find amps and ohms.)

3. Determine the quantities indicated.



$R_1 = 7\,\Omega$
$R_2 = 3\,\Omega$
$R_3 = 2\,\Omega$
$R_4 = 3\,\Omega$
E_A
60 V
−
+

a. R_T = ______

b. I_T = ______

c. V_{R1} = ______

d. I_{R3} = ______

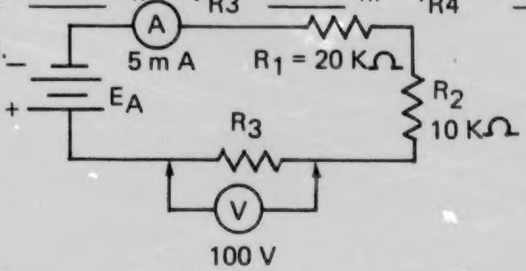
e. V_{R2} = ______

f. V_{R3} = ______

g. V_{R4} = ______

h. I_{R4} = ______

4. Determine the quantities indicated.



A
5 m A
$R_1 = 20\,K\Omega$
R_2
$10\,K\Omega$
R_3
E_A
V
100 V
−
+

a. I_T = ______

b. V_{R2} = ______

c. R3 = ______

d. V_{R1} = ______

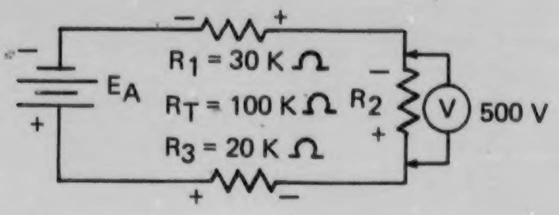
e. I_{R1} = ______

f. E_A = ______

(NOTE: 5 mA = .005A)

ASSIGNMENT SHEET #6

5. Determine the quantities indicated.

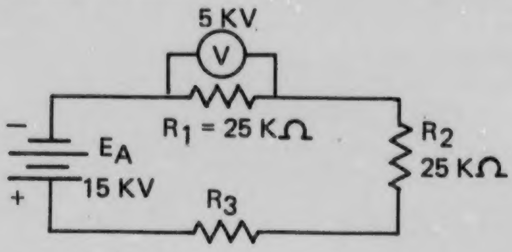


EA
R1 = 30 KΩ
RT = 100 KΩ
R2
R3 = 20 KΩ
V
500 V

a. R2 = _____ c. I_t = _____ e. V_{R3} = _____

b. I_{R3} = _____ d. V_{R1} = _____ f. E_A = _____

6. Determine the quantities indicated.



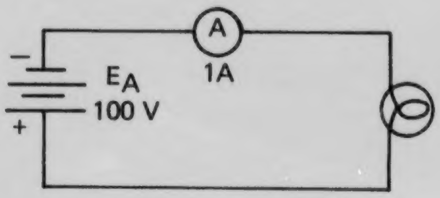
5 KV
V
R1 = 25 KΩ
EA
15 KV
R3
R2
25 KΩ

a. I_t = _____ c. R3 = _____ e. R_T = _____

b. V_{R2} = _____ d. V_{R3} = _____ f. I_{R3} = _____

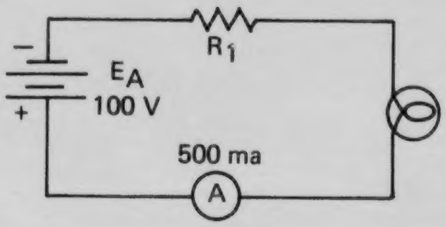
7. What resistance value will the lamp have?

R_L = _____



8. In this circuit, if you wanted the lamp in problem 7 to operate at 50v, what would the value of R_1 have to be?

R_1 = _____

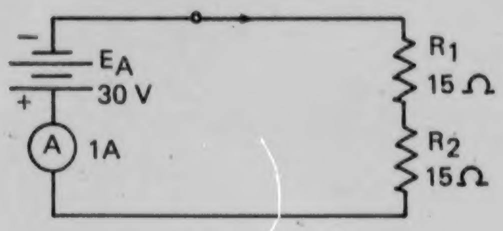


R1
EA
100 V
500 ma
A

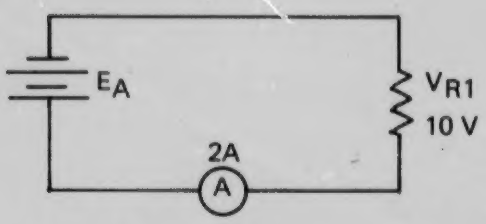
SERIES CIRCUITS
UNIT X

ASSIGNMENT SHEET #7--COMPUTE THE POWER DISSIPATED IN A RESISTIVE SERIES CIRCUIT

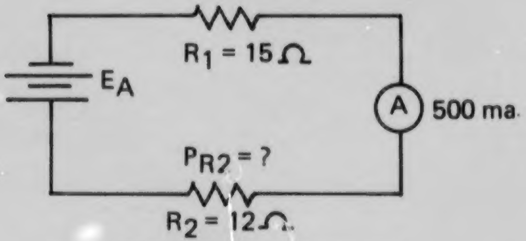
1. P_T = ______


–
+
E_A
30 V
A
1A
R_1
15 Ω
R_2
15 Ω

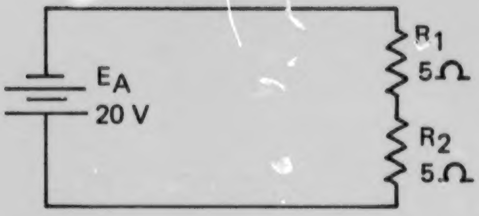
2. P_{R1} = ______


E_A
V_{R1}
10 V
2A
A

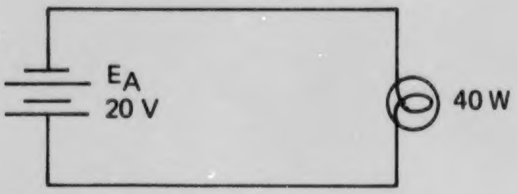
3. P_{R2} = ______


R_1 = 15 Ω
E_A
A
500 ma
P_{R2} = ?
R_2 = 12 Ω

4. P_T = ______


E_A
20 V
R_1
5 Ω
R_2
5 Ω

5. If the lamp is using 40 watts, the current equals______________



SERIES CIRCUITS
UNIT X

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

1. 50V
2. 100V
3. 40KV
4. 1000V or 1KV
5. 340V
6. 100V

Assignment Sheet #2

1. True
2. C
3. 25V
4. 45V
5. 30V

Assignment Sheet #3

1. 6
2. 5
3. 3

Assignment Sheet #4

1. 2A
2. 500 mA or 0.5 A
3. 40 mA

Assignment Sheet #5

1. 2A
2. 2A
3. 1A
4. 20V
5. 2
6. 20V
7. 50K Ω
8. 82V

Assignment Sheet #6

1. 8 Ω
2. 5V

3. a. 15 Ω
   b. 4A
   c. 28V
   d. 4A
   e. 12V
   f. 8V
   g. 12V
   h. 4A

4. a. 5mA
   b. 50V
   c. 20K
   d. 100V
   e. 5mA
   f. 250V

5. a. 50K Ω
   b. 10mA
   c. 10mA
   d. 300V
   e. 200V
   f. 1KV

6. a. 200mA
   b. 5KV
   c. 25K Ω
   d. 5KV
   e. 75K Ω
   f. 200mA

7. 100 Ω

8. 100 Ω

Assignment Sheet #7

1. 30W
2. 20W
3. 3W
4. 40W
5. 2A

SERIES CIRCUITS
UNIT X

JOB SHEET #1--MEASURE VOLTAGE DROPS IN A SERIES CIRCUIT

I. Tools and materials

- A. Power supply
- B. Switch (SPST)
- C. Two resistors of the same value
- D. One resistor of a different value
- E. Voltmeter (or multimeter)

(NOTE: Your instructor will give you the value of voltage and the value of resistors to use.)

II. Procedure

A. Connect the circuit according to following schematic (Figure 1)

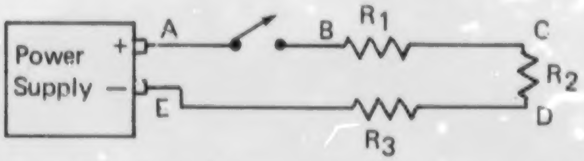


FIGURE 1

B. Close the switch

C. Use the voltmeter to read and record

E_A = ______

V_{R1} = ______

V_{R2} = ______

V_{R3} = ______

D. Add the voltage drops across the three resistors and compare the sum with the amount of applied voltage

(NOTE: Discuss if Kirchhoff's Law is confirmed by your results.)

E. Compare the voltage drops across R_1, R_2 and R_3 having the same value of ohms and with the voltage drop across the other resistor

(NOTE: Discuss how applied voltage distributes itself across resistances of unequal or of equal value.)

F. Identify the most negative point in the circuit

G. Return meter and materials to proper storage area

SERIES CIRCUITS
UNIT X

JOB SHEET #2--ANALYZE CURRENT VALUES IN A SERIES CIRCUIT

I. Tools and materials

A. Power supply

B. Switch (SPST)

C. Two resistors: R_1 = 4.7K, 1 watt; R_2 = 1K, 1W.

D. Ammeter (or multimeter)

E. Voltmeter

F. Ohmmeter

II. Procedure

A. Measure and record the ohms value of the two resistors

B. Connect a circuit as shown in the following schematic (Figure 1)

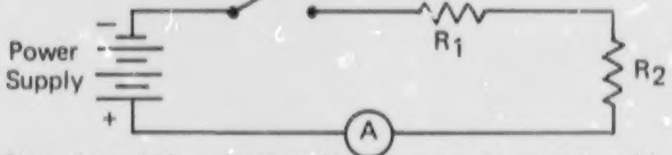


FIGURE 1

C. Close the switch and adjust the power supply output to 24 volts

D. Use the voltmeter to measure the following voltages

V_{R1} = ____ V_{R2} = ____ E_A = ____

E. Read and record the ammeter indication I = ____

F. Disconnect the circuit by opening the switch.

G. Use Ohm's law and compute:

I_{R1} = ____ I_{R2} = ____ I_T = ____ $\left(I_T = \frac{E_A}{R_T}\right)$

H. Compare the values of the various current computations, and explain the differences, if any, in these values

JOB SHEET #2

I. Return meters and materials to proper storage area

(NOTE: The following questions may be discussed in class:

1. Is the current the same through all components in a series circuit? Why?
2. Are the voltages the same across all components in a series circuit? Why?
3. How does Kirchhoff's law apply?)

SERIES CIRCUITS
UNIT X

JOB SHEET #3--ANALYZE RESISTANCE AND POWER IN A SERIES CIRCUIT

I. Tools and material

A. Power supply (0-12V)

B. Switch (SPST)

C. Two resistors (4.7K and 1K, 1 watt)

D. Ammeter

E. Multimeter

II. Procedure

A. Using the ohmmeter, measure the values of the two resistors

B. Connect the following circuit (Figure 1)

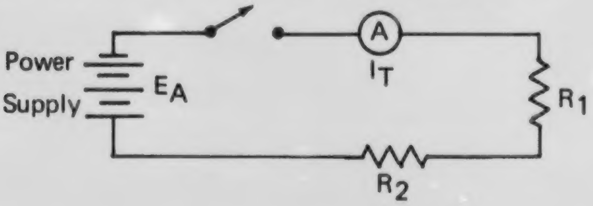


FIGURE 1

C. Close the switch and use the voltmeter (across the power supply) to adjust the applied voltage to 24 volts

(CAUTION: Do not exceed the maximum indication on the ammeter.)

D. Read and record the total current I_T = _____ and E_A = _____

E. Turn off the power supply and open the switch

F. Use the ohmmeter and measure the total resistance in the circuit

R_T = _____ (measured)

JOB SHEET #3

G. Compute R_T using measured values of E_A and I_T R_T = _____

H. Compare the ohmmeter measurement of R_T with the computed value of R_T (Step E with Step H).

(NOTE: How can the difference be explained?)

I. Compute the value of total power dissipated in the circuit

$P_T = E_A \times I_T$ = _____

J. Compute the power dissipated by each resistor

$P_{R1} = I^2R_1$ = _____ and $P_{R2} = I^2R_2$ = _____

K. Check to see if $P_T = P_{R1} + P_{R2}$

L. Compute the maximum voltage you can apply to R_1

(NOTE: $P = E^2/R$)

M. Return meters and materials to proper storage area

SERIES CIRCUITS
UNIT X

NAME ______________________________

TEST

1. Match the terms on the right with the correct definitions.

_____a. Voltage derived from Ohm's law

_____b. An abnormal connection of relatively low resistance between two points of differing potential in a circuit

_____c. A device designed to switch open a circuit automatically when a current overload exists

_____d. The sum of the series IR drops

_____e. A circuit where the same current passes through each component

_____f. The difference of voltages at two terminals of a component having opposition to current flow

_____g. A circuit with no available path for current flow

_____h. A system of conductors through which an electric current is intended to flow

_____i. An overcurrent protective device with an element that melts and opens the circuit when overheated

1. Series circuit
2. Short circuit
3. Fuse
4. Open circuit
5. Circuit
6. Circuit breaker
7. Voltage drop
8. Applied voltage
9. IR drop

2. Match the abbreviations or symbols on the right with their correct definitions.

_____a. Total current

_____b. Total voltage

_____c. Total resistance

_____d. Total power dissipated

_____e. Resistor number 1

_____f. Voltage across R_1 which equals IR_1

_____g. Power dissipated by resistor R_1

_____h. Power dissipated by resistor R_1

_____i. Voltage across R_1

1. V_1
2. P_T
3. E_T
4. P_{R1}
5. I_T
6. R_T
7. R_1
8. P_1
9. V_{R1}

3. Select the true statements concerning rules for series circuits by placing an "X" in the appropriate blanks.

______a. The sum of the voltage drops equals the applied voltage

______b. The sum of the currents in each component equals the total current

______c. Voltage drops are additive

______d. The largest current flows through the component with the largest resistance

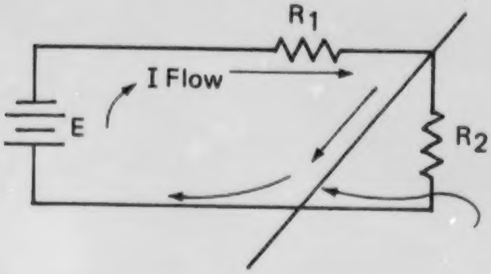
______e. The largest voltage drop is across the component with the most resistance

______f. The sum of the resistances equals the total resistance

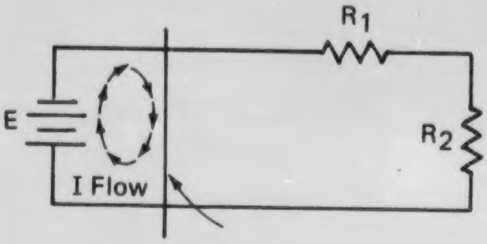
______g. Resistance is not additive

______h. The current is the same through all components

4. Distinguish between a direct and partial short circuit by placing an "X" next to the partial short circuit.



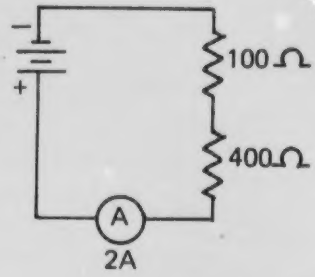
______a.



______b.

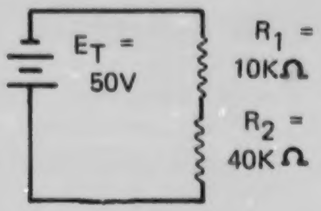
5. Determine the total voltage in the series circuit below.

E_T = ______



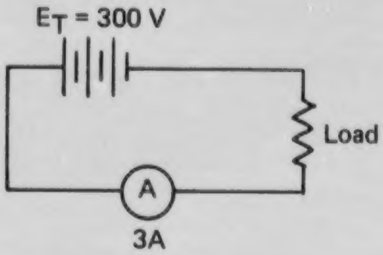
6. Determine the voltage drops across each resistor in the schematic below.

a. V_{R1} = _____v b. V_{R2} = _____v


E_T =
50V
R_1 =
10KΩ
R_2 =
40KΩ

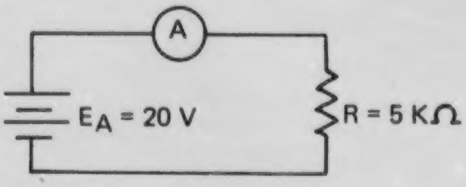
7. Determine the total resistance in the series circuit below.

R_T = _____


E_T = 300 V
Load
A
3A

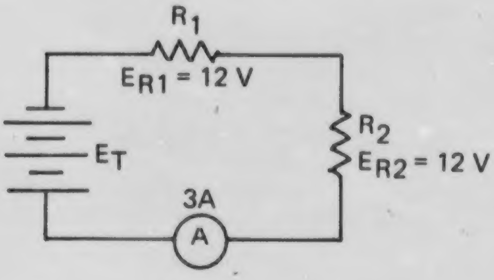
8. Determine the current in the series circuit below.

I = _____


A
E_A = 20 V
R = 5 KΩ

9. Determine the unknown circuit value in the series circuit below.

R_2 = _____


R_1
E_{R1} = 12 V
E_T
R_2
E_{R2} = 12 V
3A
A

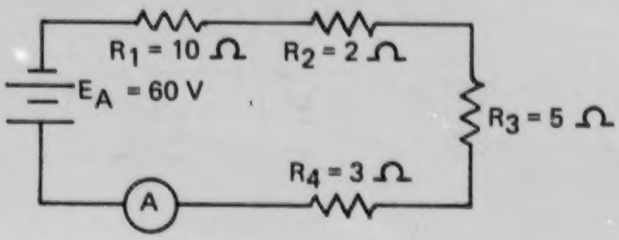
10. Determine the unknown values indicated in the resistive series circuit below.

a. R_T = ______

b. I_T = ______

c. I_{R3} = ______

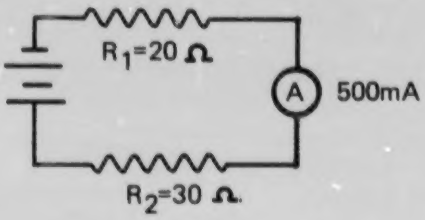
d. V_{R1} = ______



$R_1 = 10\ \Omega$
$R_2 = 2\ \Omega$
$E_A = 60$ V
$R_3 = 5\ \Omega$
$R_4 = 3\ \Omega$
A

11. Compute the power dissipated in the resistive series circuit below.

P_T = ______



R_1=20 Ω
A
500mA
R_2=30 Ω

12. Demonstrate the ability to:

a. Measure voltage drops in a series circuit.

b. Analyze current values in a series circuit.

c. Analyze resistance and power in a series circuit.

(NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

SERIES CIRCUITS
UNIT X

ANSWERS TO TEST

1. a. 9
   b. 2
   c. 6
   d. 8
   e. 1
   f. 7
   g. 4
   h. 5
   i. 3

2. a. 5
   b. 3
   c. 6
   d. 2
   e. 7
   f. 1
   g. 4 or 8
   h. 8 or 4
   i. 9

3. a, c, e, f, h

4. a

5. 1000v or 1 KV

6. a. 10v
   b. 40v

7. 100 Ω

8. 4mA or .004A

9. 4

10. a. 20 Ω

    b. 3A

    c. 3A

    d. 30V

11. 12.5W

12. Performance skills evaluated to the satisfaction of the instructor.

PARALLEL CIRCUITS
UNIT XI

UNIT OBJECTIVE

After completion of this unit, the student should be able to select true statements regarding the rules governing voltage and current in a parallel circuit and determine the formula to use for the total resistance of parallel circuits. The student should also be able to perform a circuit analysis of a parallel circuit and measure voltage, current, resistance, and power in a parallel circuit. This knowledge will be evidenced by correctly performing the procedures outlined on the assignment and job sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms associated with parallel circuits with their definitions.
2. Select true statements regarding the rules governing voltage in a parallel circuit.
3. Select true statements regarding the rules governing current in a parallel circuit.
4. Determine the formula to use and the total resistance in given resistive parallel circuits.
5. Perform a circuit analysis of a parallel circuit.
6. Select true statements regarding the effect of opens or shorts in parallel circuits.
7. Demonstrate the ability to:
    a. Measure voltage, current, and resistance in a parallel circuit.
    b. Measure power in a parallel circuit.

PARALLEL CIRCUITS
UNIT XI

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information, assignment, and job sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives

V. Discuss information and assignment sheets.

VI. Demonstrate and discuss the procedures outlined in the job sheets.

VII. Give test

INSTRUCTIONAL MATERIALS

I. Included in this unit:

   A. Objective sheet

   B. Information sheet

   C. Transparency masters

      1. TM 1--Parallel Circuit
      2. TM 2--Memory Wheel for Solving Problems
      3. TM 3--Voltage in a Parallel Circuit
      4. TM 4--Current Flow in a Parallel Circuit
      5. TM 5--Resistance in Parallel Circuits
      6. TM 6--The Reciprocal Resistance Method
      7. TM 7--Finding the Total Resistance in Parallel Circuits
      8. TM 8--Finding Current in a Parallel Circuit

   D. Assignment sheets

      1. Assignment Sheet #1--Calculate Current and Voltage in Parallel Circuits
      2. Assignment Sheet #2--Calculate Resistance in Parallel Circuits

3. Assignment Sheet #3--Calculate Power in Parallel Circuits
4. Assignment Sheet #4--Calculate Various Values in Parallel Circuits
5. Assignment Sheet #5--Perform Circuit Analysis for Parallel Circuits
6. Assignment Sheet #6--Answer Questions about Shorts and Opens in Parallel Circuits

E. Answers to assignment sheets

F. Job sheets

1. Job Sheet #1--Measure Voltage, Current, and Resistance in a Parallel Circuit
2. Job Sheet #2--Compute Power in a Parallel Circuit

G. Test

H. Answers to test

II. References:

A. Grob, Bernard. *Basic Electronics.* New York: McGraw-Hill Book Co., 1979

B. Marcus, Abraham. *Basic Electronics.* Englewood Cliffs, NJ: Prentice-Hall, Inc., 1971.

PARALLEL CIRCUITS
UNIT XI

INFORMATION SHEET

I. Terms and definitions

A. Parallel circuit--An electronic circuit which provides more than one path (or branch) for current flow (Transparency 1)

B. The reciprocal of a number--One (1) divided by that number

Example: The reciprocal of 2 is 1/2 (one divided by two)
The reciprocal of 4 is 1/4 (one divided by four)

C. Variable--Changeable or capable of being changed

Example: A resistor whose value can be changed is called a variable resistor (or potentiometer)

D. Parameter (pronounced Pah-RAM-ah-ter)--An element or condition which determines the value of circuit variables

Example: In the problem "With input voltage at 100V and current at the 2A, what is the circuit resistance?," the given voltage and current are the parameters which will be used as the basis for determining circuit resistance (the variable)

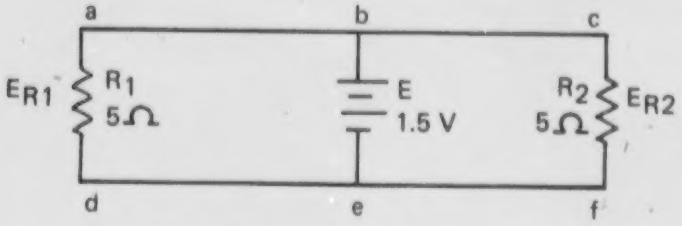
E. Circuit analysis--Applying Ohm's law and other rules to determine the effect of certain parameters on circuit variables (Transparency 2)

II. Voltage in a parallel circuit (Transparency 3)

A. The voltage is the same across parallel branches (Figure 1)

Example: In the parallel circuit below, E_{ad} and E_{cf} are the same (1.5V) because points a, b, and c, and points d, e, and f are exactly the same

FIGURE 1

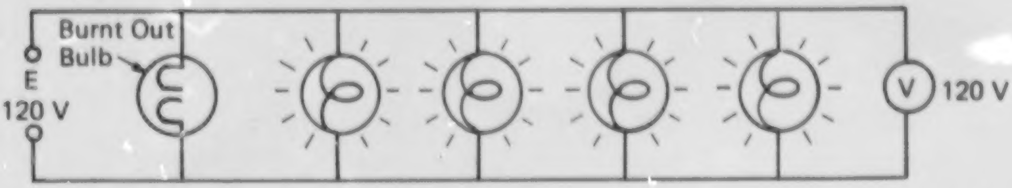


INFORMATION SHEET

B. Branch elements in a parallel circuit work independently of each other

(NOTE: If Christmas tree lights are connected in parallel, the whole string does not go out when one bulb burns out. (See Figure 2). This is because the voltage remains across parallel branches even though one branch is open. If the bulbs were connected in series, the whole string of bulbs would go out when any one burned out.)

FIGURE 2



III. Current in a parallel circuit (Transparency 4)

A. A part of the total circuit current flows through each branch

B. The current of each branch equals the voltage divided by the resistance of the branch ($I_1 = E/R_1$)

C. The main line current (I_T) equals the sum of the branch currents ($I_1 + I_2 + I_3 + \ldots$)

IV. Resistances in parallel (Transparencies 5, 6, 7, and 8)

A. Ohm's law is used to determine total resistance if current is known: $R_T = E/I_T$

B. If current is not known, the reciprocal resistance formula is used to compute total resistance:

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots$$

or

$$R_T = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots}$$

INFORMATION SHEET

C. Equal branch method used if resistors of equal value (R) are connected in parallel:

$R_T = R/N$ where N is the total number of equal resistors

Example: If three 30-ohm resistors are connected in parallel, R_T equals 30/3 or 10 ohms

D. Unequal branch method used when two resistors (R_1 & R_2) of unequal value are connected in parallel:

$$R_T = \frac{R_1 \times R_2}{R_1 + R_2}$$

E. Parallel rule: The total resistance of parallel resistors is always less than the resistance of any one branch

V. Circuit analysis

A. Circuit parameters

1. Voltage values
2. Current values
3. Resistance values
4. Power values

B. If one circuit parameter is changed (increased or decreased), other circuit variables (elements) will either:

1. Increase, or
2. Decrease, or
3. Remain the same

C. Symbols for changing values

1. Increase - ↑
2. Decrease - ↓
3. Remain the same - →

INFORMATION SHEET

D. Ohm's law is used to determine the effect of changing parameters on circuit component values

Example: Changing parameter--If applied voltage (E_a) in the circuit below (Figure 1) is increased...

Question--...what happens to the values of other circuit variables?

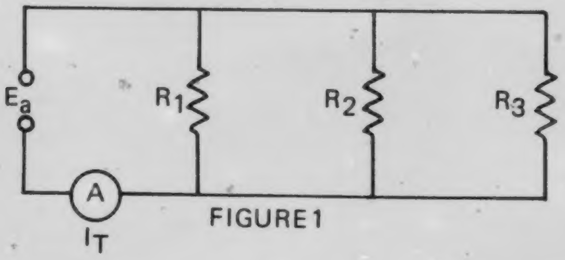


FIGURE 1

Answer:

E_a ↑	↑	→	↑	↑	→	↑
	I_T	R_T	P_T	I_{R1}	R_1	E_{R1}

FIGURE 2

The block form and arrow symbols (Figure 2) are used for laying out the circuit analysis

The laws applicable are as follows:

1. Total current (I_T) increases, based on the formula E = IR (resistors R_1, R_2, and R_3, and hence total Resistance, R_T, cannot change because they are fixed values.)
2. Total resistance (R_T) remains the same, as explained in (1) above
3. Total power (P_T) increases, based on formula $P = I^2R$ (resistance remains fixed)
4. The voltage across R_1 (E_{R1}) increases, since this voltage is the same as the applied voltage (E_a)
5. Resistance of R_1 remains the same, as explained in (1) above

INFORMATION SHEET

6. Current through R_1 (I_{R1}) increases, because current is split proportionately among the branches of a parallel circuit and hence must increase proportionately in each branch if total current increases.

VI. Opens and shorts in parallel circuits

A. Opens

1. An open in the main line of a parallel circuit before the first component prevents current flow through the entire circuit (Figure 1)

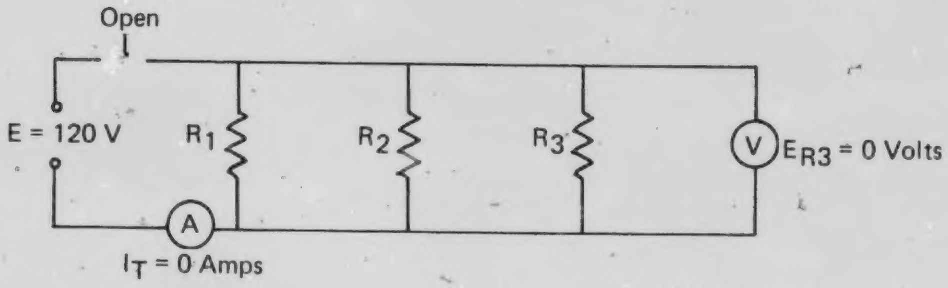

Open
E = 120 V
R1
R2
R3
V
ER3 = 0 Volts
A
IT = 0 Amps

FIGURE 1

2. An open in a branch of a parallel circuit prevents current flow through the open branch only; current will continue to flow through the remaining branches (Figure 2)

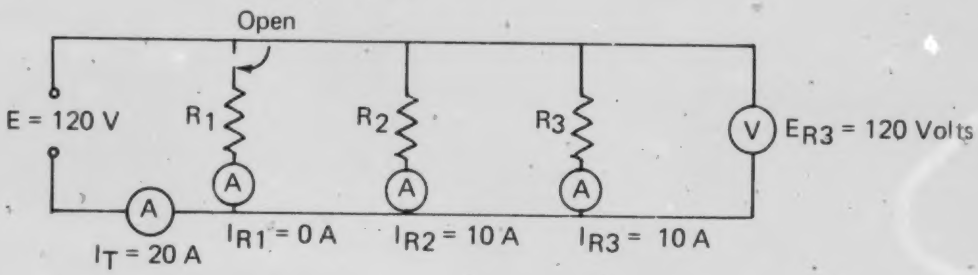

Open
E = 120 V
R1
R2
R3
V
ER3 = 120 Volts
A
A
A
A
IT = 20 A
IR1 = 0 A
IR2 = 10 A
IR3 = 10 A

FIGURE 2

(NOTE: An open branch causes an increase in total resistance and hence a decrease in total current, since the applied voltage remains the same.)

INFORMATION SHEET

B. Shorts

1. Direct short--A direct short across a parallel circuit shunts the total current through the short and away from all branches (Figure 3)

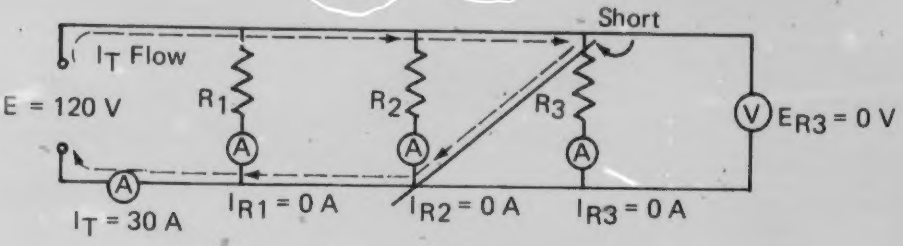
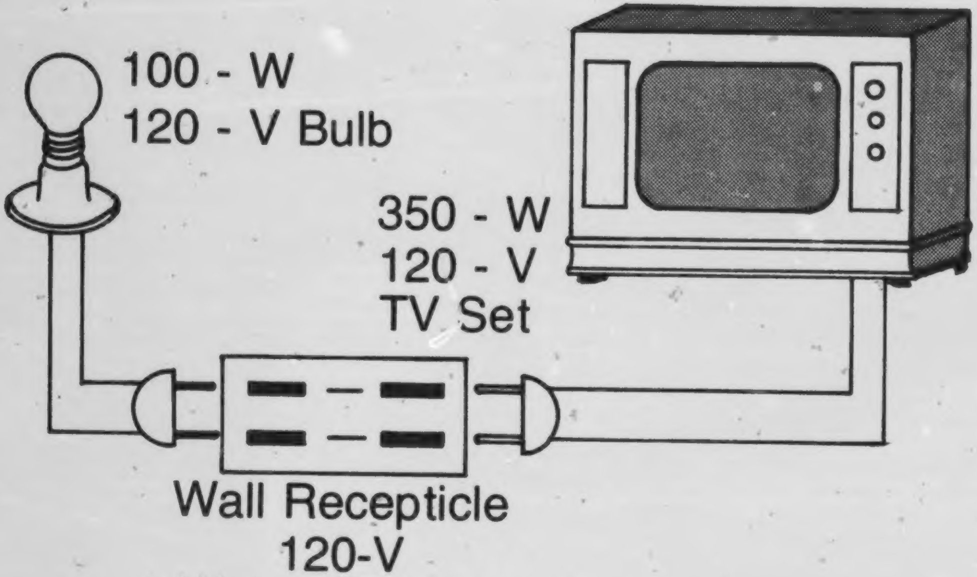
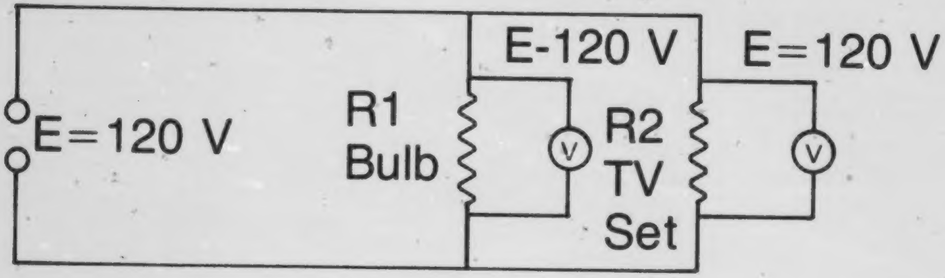

Short
I_T Flow
E = 120 V
R_1
R_2
R_3
E_{R3} = 0 V
I_T = 30 A
I_{R1} = 0 A
I_{R2} = 0 A
I_{R3} = 0 A

FIGURE 3

Parallel Circuit


100 - W
120 - V Bulb
350 - W
120 - V
TV Set
Wall Recepticle
120-V

Wiring Diagram

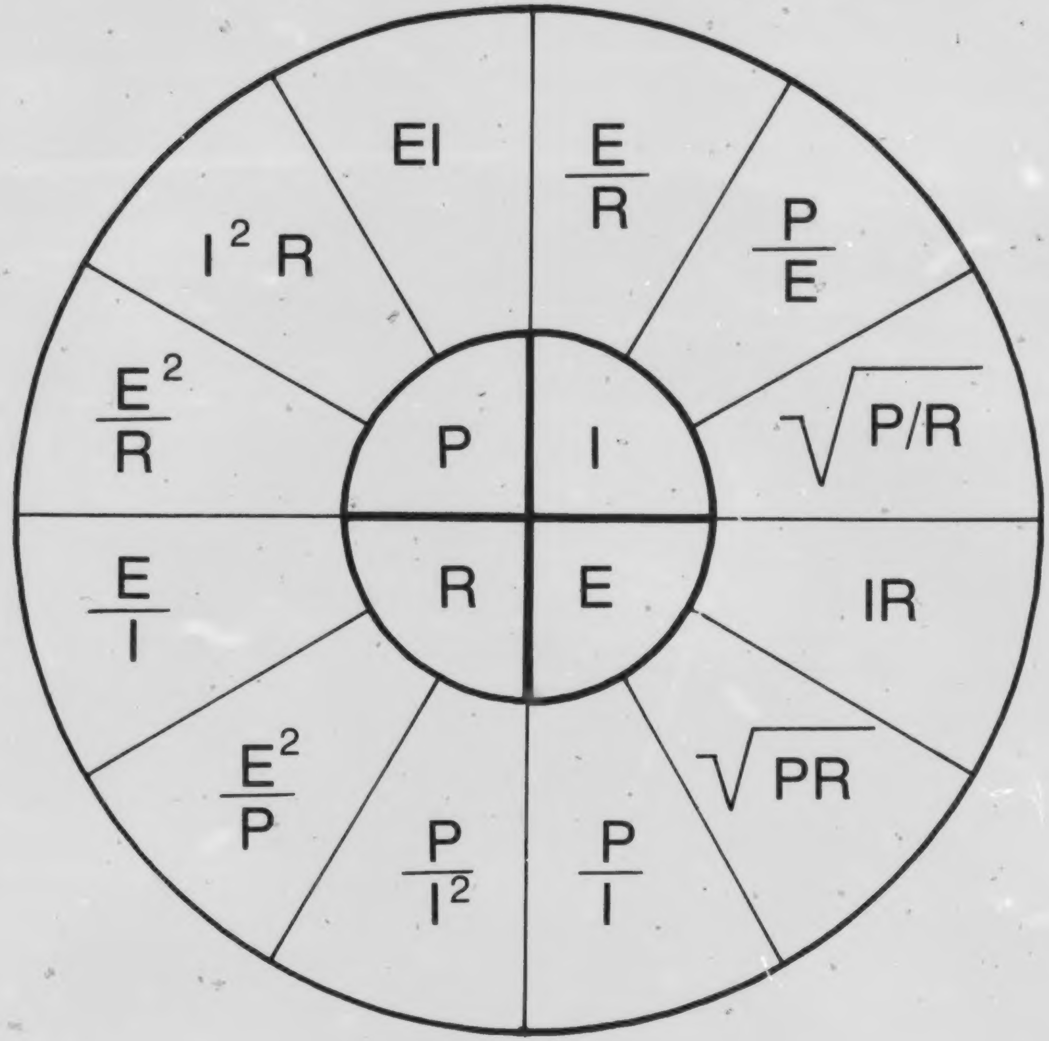

E-120 V
E=120 V
E=120 V
R1
Bulb
R2
TV
Set
V
V

Schematic

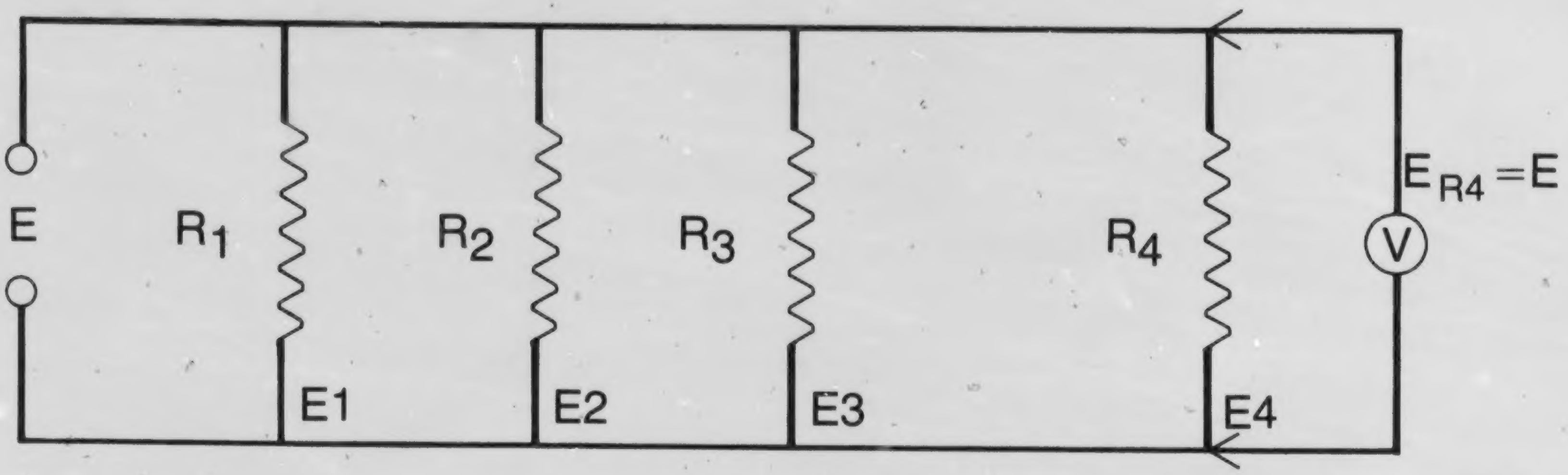
This circuit provides two paths for current flow: Through R1 (Bulb) and through R2 (TV Set).

Note that the voltage across both the bulb and the TV set is the same as the applied voltage (120 v).

Memory Wheel for Solving Problems


P
I
R
E
EI
$\frac{E}{R}$
$\frac{P}{E}$
$\sqrt{P/R}$
IR
$\sqrt{PR}$
$\frac{P}{I}$
$\frac{P}{I^2}$
$\frac{E^2}{P}$
$\frac{E}{I}$
$\frac{E^2}{R}$
$I^2 R$

Voltage in a Parallel Circuit

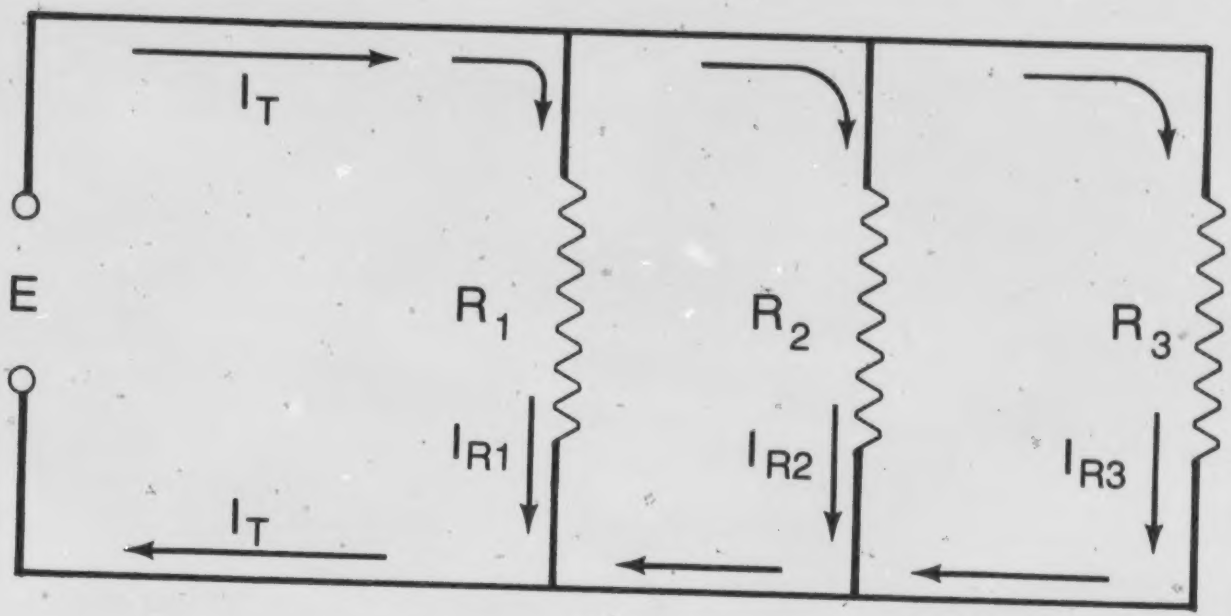

E
R1
R2
R3
R4
E1
E2
E3
E4
V
$E_{R4} = E$

The voltage across each branch of a parallel circuit is the same value.

or

$$E = E1 = E2 = E3 = \ldots$$

Current Flow in a Parallel Circuit


I_T
E
R_1
R_2
R_3
I_{R1}
I_{R2}
I_{R3}
I_T

The total current flowing through a parallel circuit is the sum of the currents flowing through each branch.

In the above circuit: $I_T = I_{R1} + I_{R2} + I_{R3}$

Resistance in Parallel Circuits

The reciprocal of the total resistance of a parallel circuit is equal to the sum of the reciprocals of the individual resistances

or

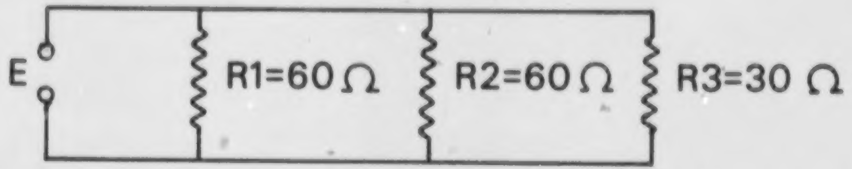
$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4} + \frac{1}{R_5} + \cdots$$

or

$$R_T = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4} + \frac{1}{R_5} + \ldots}$$

The Reciprocal Resistance Method

For Calculating Total Resistance
in a Parallel Circuit: $1/R_T = 1/R1 + 1/R2 + 1/R3$



Step 1: Find Least Common Denominator and Add the Reciprocals:

$$\frac{1}{60} = \frac{1}{60}$$

$$\frac{1}{60} = \frac{1}{60}$$

$$\frac{1}{30} = \frac{2}{60}$$

$$\frac{4}{60} \text{ Total}$$

Step 2: Invert the Reciprocals:

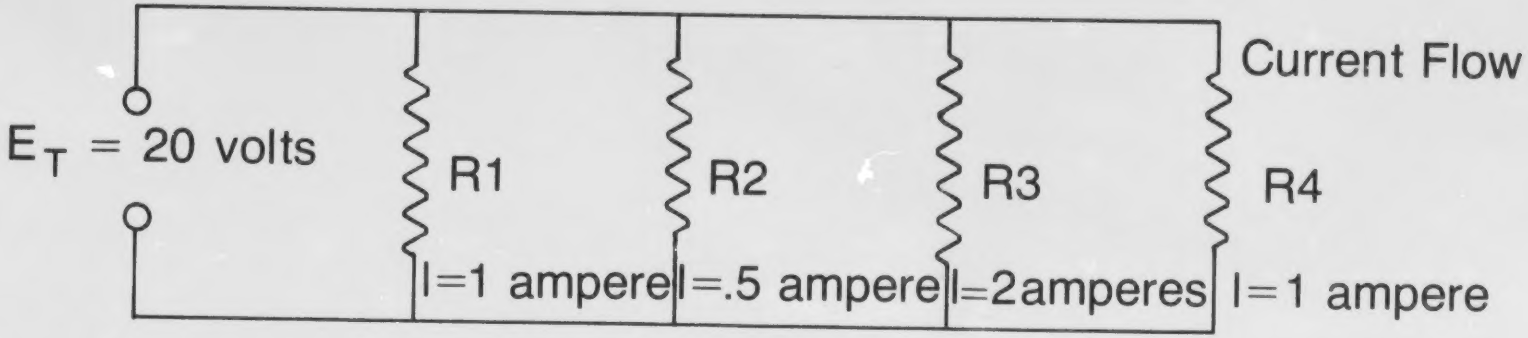
$$\frac{1}{R_T} = \frac{4}{60}$$

$$R_T = \frac{60}{4}$$

Step 3: Solve For R_T:

$$R_T = 15\Omega$$

Finding the Total Resistance in Parallel Circuits


Current Flow
E_T = 20 volts
R1
R2
R3
R4
I=1 ampere
I=.5 ampere
I=2amperes
I=1 ampere

$$R_T = \frac{E_T}{I_T} = \frac{20}{4.5} = 4.4 \text{ ohms}$$

$$R1 = \frac{20 \text{ volts}}{1 \text{ ampere}} = 20 \text{ ohms}$$

$$R2 = \frac{20 \text{ volts}}{.5 \text{ ampere}} = 40 \text{ ohms}$$

$$R3 = \frac{20 \text{ volts}}{2 \text{ amperes}} = 10 \text{ ohms}$$

$$R4 = \frac{20 \text{ volts}}{1 \text{ ampere}} = 20 \text{ ohms}$$

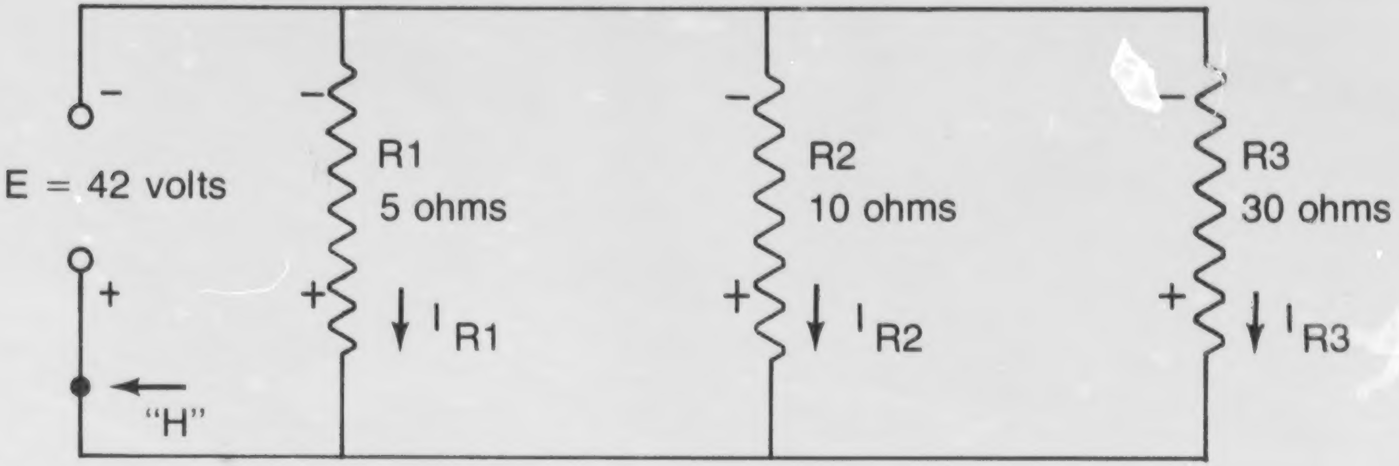
$$\frac{1}{R_T} = \frac{1}{R1} + \frac{1}{R2} + \frac{1}{R3} + \frac{1}{R4}$$

$$\frac{1}{R_T} = \frac{1}{20} + \frac{1}{40} + \frac{1}{10} + \frac{1}{20}$$

$$\frac{1}{R_T} = \frac{2 + 1 + 4 + 2}{40} = \frac{9}{40}$$

$$R_T = \frac{40}{9} = 4.4 \text{ ohms}$$

Finding Current in a Parallel Circuit


−
E = 42 volts
+
"H"
R1
5 ohms
I_{R1}
R2
10 ohms
I_{R2}
R3
30 ohms
I_{R3}
−
+

I_T = __________(Amperes)

How much current is passing through point "H" in this circuit? There are two methods for determining total current in this circuit:

1. Find the current flowing through each branch (ex.: $I_{R1} = \frac{E}{R1}$), then add all 3 branch currents ($I_T = I_{R1} + I_{R2} + I_{R3}$).
2. Find the total resistance using the reciprocal resistance formula, then calculate total current ($I_T = \frac{E}{R_T}$).

PARALLEL CIRCUITS
UNIT XI

ASSIGNMENT SHEET #1--CALCULATE CURRENT AND VOLTAGE IN PARALLEL CIRCUITS

1. Calculate quantities indicated.

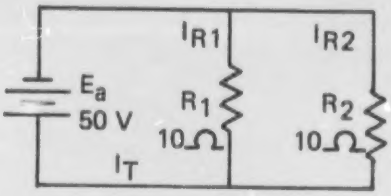
   a. E_{R1} ______

   b. I_{R1} ______

   c. E_{R2} ______

   d. I_{R2} ______

   e. I_T ______


I_{R1}
I_{R2}
E_a
50 V
R_1
10Ω
R_2
10Ω
I_T

2. Calculate quantities indicated.

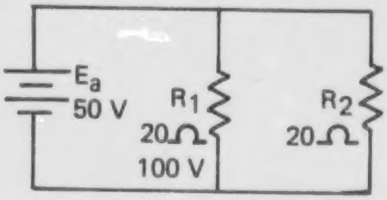
   a. I_{R1} ______

   b. E_{R2} ______

   c. I_{R2} ______

   d. I_T ______

   e. E_a ______


E_a
50 V
R_1
20Ω
100 V
R_2
20Ω

3. Calculate quantities indicated.

   a. I_{R1} ______

   b. I_{R2} ______

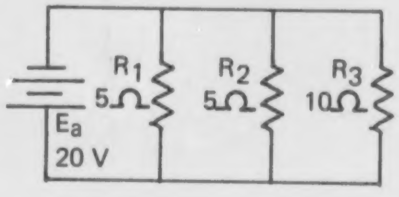
   c. I_{R3} ______

   d. I_T ______

   e. E_{R1} ______

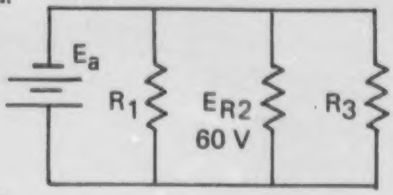
   f. E_{R2} ______

   g. E_{R3} ______


R_1
5Ω
R_2
5Ω
R_3
10Ω
E_a
20 V

ASSIGNMENT SHEET #1

4. Calculate quantities indicated.

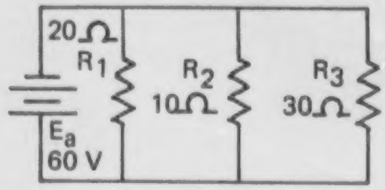

E_a
R_1
E_{R2}
60 V
R_3

a. E_{R1} ______

b. E_{R3} ______

c. E_a ______

5. Calculate quantities indicated.


20Ω
R_1
R_2
10Ω
R_3
30Ω
E_a
60 V

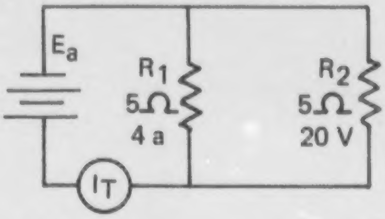
a. I_1 ______

b. I_2 ______

c. I_3 ______

d. I_T ______

6. Calculate quantities indicated.


E_a
R_1
5Ω
4 a
R_2
5Ω
20 V
I_T

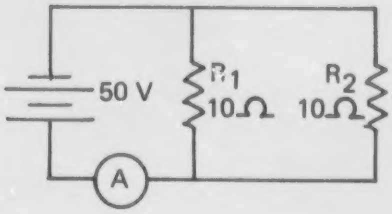
a. I_2 ______

b. I_T ______

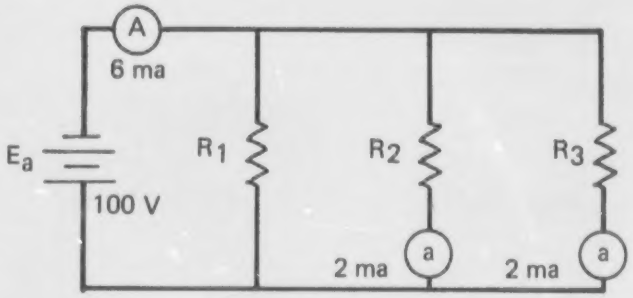
c. E_{R1} ______

d. E_a ______

7. If you measured current where ammeter is located, what should it indicate? ______


50 V
R_1
10Ω
R_2
10Ω
A

8. Calculate quantities indicated.


A
6 ma
E_a
100 V
R_1
R_2
R_3
2 ma
a
2 ma
a

a. I_1 ______

b. E_{R1} ______

c. E_a ______

d. I_T ______

e. E_{R2} ______

f. E_{R3} ______

PARALLEL CIRCUITS
UNIT XI

ASSIGNMENT SHEET #2--CALCULATE RESISTANCE IN PARALLEL CIRCUITS

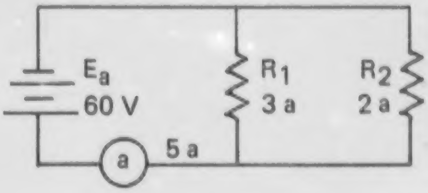
1. Calculate quantities indicated.

   a. R_1 _____

   b. R_2 _____

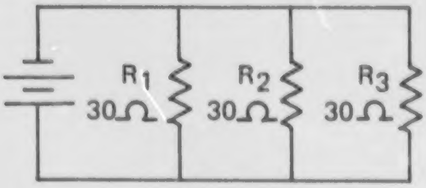
   c. R_T _____

   d. $\frac{E_a}{I_R}$ = _____



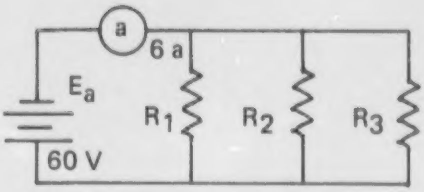
E_a
60 V
R_1
3 a
R_2
2 a
a
5 a

2. Calculate R_T _____



R_1
30Ω
R_2
30Ω
R_3
30Ω

3. a. Calculate R_T _____

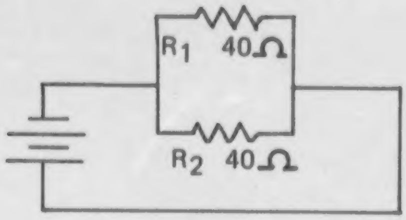


a
6 a
E_a
60 V
R_1
R_2
R_3

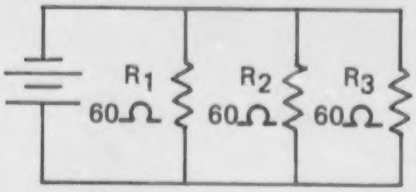
   b. If the three resistors are equal in value, R1 = _____ ohms.

ASSIGNMENT SHEET #2

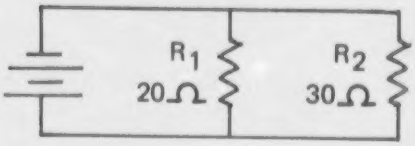
4. Calculate R_T________


R1 40Ω
R2 40Ω

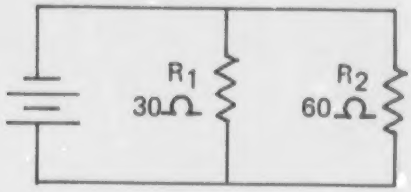
5. Calculate R_T________


R1 60Ω
R2 60Ω
R3 60Ω

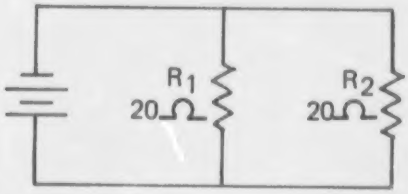
6. Calculate R_T________


R1 20Ω
R2 30Ω

7. Calculate R_T________

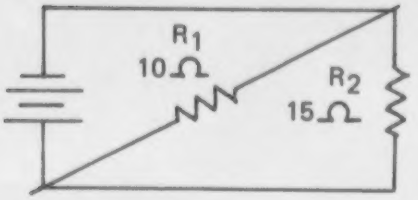

R1 30Ω
R2 60Ω

8. Calculate R_T________

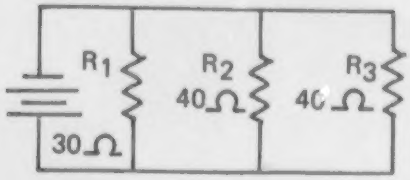

R1 20Ω
R2 20Ω

ASSIGNMENT SHEET #2

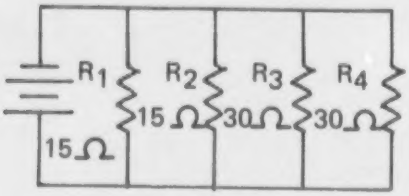
9. Calculate R_T________


R1
10 Ω
R2
15 Ω

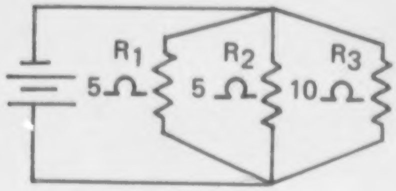
10. Calculate R_T________


R1
30 Ω
R2
40 Ω
R3
40 Ω

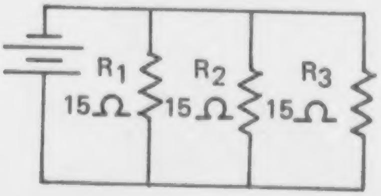
11. Calculate R_T________


R1
15 Ω
R2
15 Ω
R3
30 Ω
R4
30 Ω

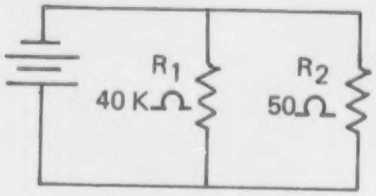
12. Calculate R_T________


R1
5 Ω
R2
5 Ω
R3
10 Ω

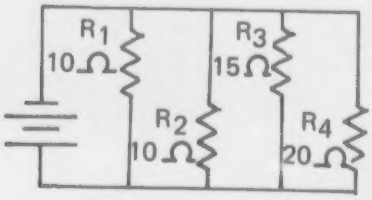
13. Match


R1
15 Ω
R2
15 Ω
R3
15 Ω

_____a.


R1
40 KΩ
R2
50 Ω

_____b.


R1
10 Ω
R2
10 Ω
R3
15 Ω
R4
20 Ω

_____c.

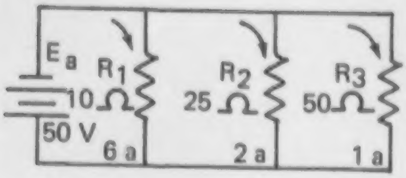
1. Unequal branch method (product over sum)
2. Reciprocal method
3. Equal branch method

(NOTE: Method 2 can, naturally, be used for all. Choose the fastest method.)

PARALLEL CIRCUITS
UNIT XI

ASSIGNMENT SHEET #3--CALCULATE POWER IN PARALLEL CIRCUITS

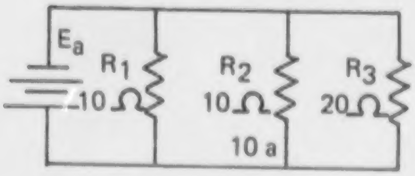
1. Calculate P_T



E_a
R_1
10 Ω
50 V
6 a
R_2
25 Ω
2 a
R_3
50 Ω
1 a

_____Watts

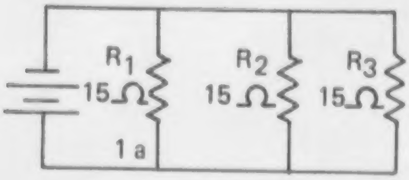
2. Calculate P_T



E_a
R_1
10 Ω
R_2
10 Ω
10 a
R_3
20 Ω

_____Watts

3. Calculate P_T



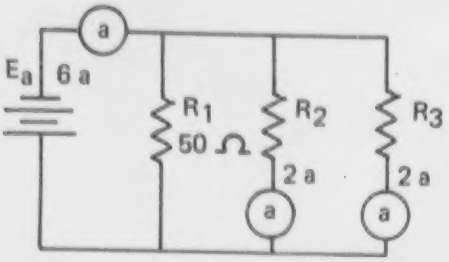
R_1
15 Ω
1 a
R_2
15 Ω
R_3
15 Ω

_____Watts

PARALLEL CIRCUITS
UNIT XI

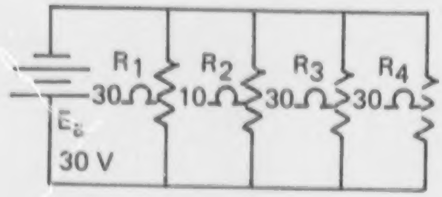
ASSIGNMENT SHEET #4--CALCULATE VARIOUS VALUES IN PARALLEL CIRCUITS

1. Calculate quantities indicated.


a
E_a
6 a
R_1
50 Ω
R_2
R_3
2 a
2 a
a
a

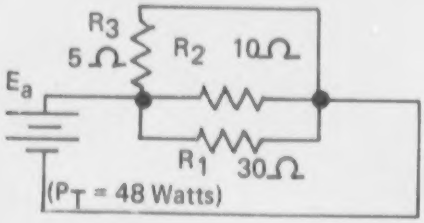
a. E_{R1} ________
b. E_a ________
c. R_T ________
d. R_2 ________
e. R_3 ________
f. P_T ________

2. Calculate quantities indicated.


R_1
30Ω
R_2
10Ω
R_3
30Ω
R_4
30Ω
E_a
30 V

a. R_T ________
b. I_1 ________
c. I_2 ________
d. I_3 ________
e. I_4 ________
f. I_T ________

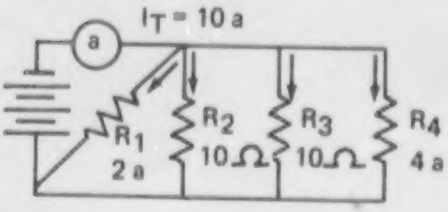
3. Calculate quantities indicated.


R_3
5 Ω
R_2
10Ω
E_a
R_1
30Ω
(P_T = 48 Watts)

a. R_T ________
b. I_T ________
c. E_a ________
d. I_{R1} ________

ASSIGNMENT SHEET #4

4. Calculate quantities indicated.


I_T = 10 a
a
R_1
2 a
R_2
10 Ω
R_3
10 Ω
R_4
4 a

a. E_a ________

b. R_4 ________

c. I_{R2} ________

d. I_{R3} ________

e. R_T ________

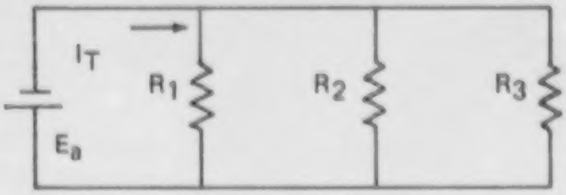
f. P_T ________

PARALLEL CIRCUITS
UNIT XI

ASSIGNMENT SHEET #5--PERFORM CIRCUIT ANALYSIS FOR PARALLEL CIRCUITS

Directions: Insert arrow symbols as appropriate in the blocks to indicate increase, decrease, or remain the same.

(Use this circuit
for problems 1
and 2)



1.

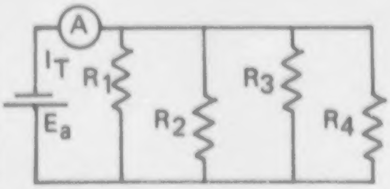
E_a ↓												
	I_T	R_T	P_T	I_{R1}	I_{R2}	I_{R3}	E_{R1}	E_{R2}	E_{R3}	R_1	R_2	R_3

2.

E_a ↑												
	I_T	R_t	P_t	I_{R1}	I_{R2}	I_{R3}	E_{R1}	E_{R2}	E_{R3}	R_1	R_2	R_3

3.

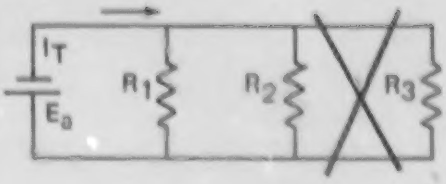
Add R_4												
	I_t	R_t	E_t	P_t	R_1	R_3	E_{R1}	E_{R2}	E_{R3}	I_{R1}	I_{R2}	I_{R3}



ASSIGNMENT SHEET #5

4.

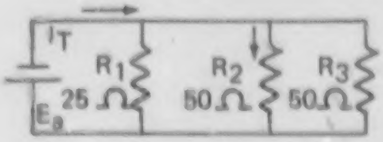
Remove R_3										
	I_T	R_T	E_T	P_T	E_{R1}	E_{R2}	R1	R2	I_{R1}	I_{R1}



I_T
E_a
R_1
R_2
R_3

5.

R_2 ↓												
	I_T	R_T	E_T	P_T	R1	R3	E_{R1}	E_{R2}	E_{R3}	I_{R1}	I_{R2}	I_{R3}



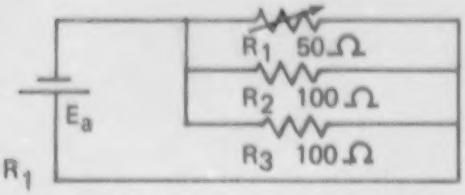
I_T
R_1
25 Ω
E_a
R_2
50 Ω
R_3
50 Ω

6. There are three parts to this problem.

a. Increase E_a

b. Remove R_3

c. Change R_1 to 100 ohm; that is, increase R_1



E_a
R_1 50 Ω
R_2 100 Ω
R_3 100 Ω

For each of the three problems, assume that the other elements remain constant.

a. E_a ↑			▨											
b. Remove R_3							▨				▨			▨
c. R_1 ↑												▨		
	I_t	R_t	E_t	P_t	I_{R1}	I_{R2}	I_{R3}	E_{R1}	E_{R1}	E_{R2}	E_{R3}	R1	R2	R3

PARALLEL CIRCUITS
UNIT XI

ASSIGNMENT SHEET #6--ANSWER QUESTIONS ABOUT SHORTS AND OPENS IN PARALLEL CIRCUITS

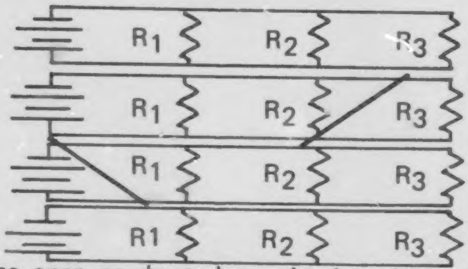
1. Match.

_____a.

_____b.

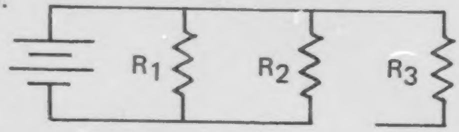
_____c.

_____d.



1. Short
2. Main line open
3. Branch open

2. Locate the open or short shown in the schematic, then answer the questions below comparing the circuit shown to a primary connected circuit using R_1, R_2 and R_3 in parallel.



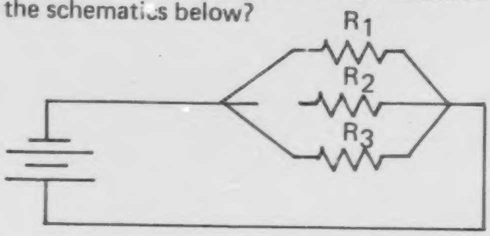
a. I_T would _______________ (increase/decrease)

b. R_T would _______________ (increase/decrease)

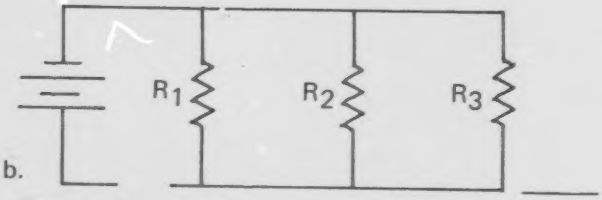
c. P_T would _______________ (increase/decrease)

3. Which branch or branches will be knocked out of the circuit by the opens shown in the schematics below?

a.



_____



b. _____

PARALLEL CIRCUITS
UNIT XI

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1:

1. a. 50v
   b. 5a
   c. 50v
   d. 5a
   e. 10a

2. a. 5a
   b. 100v
   c. 5a
   d. 10a
   e. 100v

3. a. 4a
   b. 4a
   c. 2a
   d. 10a
   e. 20v
   f. 20v
   g. 20v

4. a. 60v
   b. 60v
   c. 60v

5. a. 3a
   b. 6a
   c. 2a
   d. 11a

6. a. 4a
   b. 8a
   c. 20v
   d. 20v

7. 10a

8. a. 2ma
   b. 100v
   c. 100v
   d. 6ma
   e. 100v
   f. 100v

Assignment Sheet #2

1. a. 20Ω
   b. 30Ω
   c. 12Ω
   d. 12Ω

2. 10Ω

3. a. 10Ω
   b. 30Ω

4. 20Ω

5. 20Ω

6. 12Ω

7. 20Ω

8. 10Ω

9. 6Ω

10. 12Ω

11. 5Ω

12. 2Ω

13. a. (3)
    b. (1)
    c. (2)

Assignment Sheet #3

1. 450
2. 2500 watts
3. 45 watts

Assignment Sheet #4

1.	a.	100V	2.	a.	5Ω	3.	a.	3Ω	4.	a.	20v
		100V		b.	1A		b.	4A		b.	5Ω
	c.	16.7Ω		c.	3A		c.	12V		c.	2a
	d.	50Ω		d.	1A		d.	0.4a or 400ma		d.	2a
	e.	50Ω		e.	1A					e.	2Ω
	f.	600W		f.	6A					f.	200 watts

Assignment Sheet #5

1.

E_a↓	↓	→	↓	↓	↓	↓	↓	↓	↓	→	→	→
	I_T	R_T	P_T	I_{R1}	I_{R2}	I_{R3}	E_{R1}	E_{R2}	E_{R3}	R_1	R_2	R_3

2.

E_a↑	↑	→	↑	↑	↑	↑	↑	↑	↑	→	→	→
	I_T	R_t	P_t	I_{R1}	I_{R2}	I_{R3}	E_{R1}	E_{R2}	E_{R3}	R_1	R_2	R_3

3.

Add R_4	↑	↓	→	↑	→	→	→	→	→	→	→	→	→
	I_t	R_t	E_t	P_t	R_1	R_2	R_3	E_{R1}	E_{R2}	E_{R3}	I_{R1}	I_{R2}	I_{R3}

4.

Remove R_3	↓	↑	→	↓	→	→	→	→	→	→
	I_T	R_T	E_T	P_T	E_{R1}	E_{R2}	R1	R2	I_{R1}	I_{R1}

5.

R_2↓	↑	↓	→	↑	→	→	→	→	→	→	↑	→
	I_T	R_T	E_T	P_T	R1	R3	E_{R1}	E_{R2}	E_{R3}	I_{R1}	IR2	I_{R3}

6.

a.	E_a ↑	↑	→	▨	↑	↑	↑	↑	↑	↑	→	→	→
b.	Remove R3	↓	↑	→	↓	→	→	▨	→	→	▨	→	→	▨
c.	R_1 ↑	↓	↑	→	↓	↓	→	→	→	→	→	▨	→	→
		I_t	R_t	E_t	P_t	I_{R1}	I_{R2}	I_{R3}	E_{R1}	E_{R2}	E_{R3}	R1	R2	R3

Assignment Sheet #6:

1. a. 2
   b. 1
   c. 1
   d. 3
2. a. Decrease
   b. Increase
   c. Decrease
3. a. R2
   b. R1, R2, R3 or all branches

PARALLEL CIRCUITS
UNIT XI

JOB SHEET #1--MEASURE VOLTAGE, CURRENT, AND RESISTANCE IN A PARALLEL CIRCUIT

I. Equipment and materials

- A. 1.5 battery or equivalent
- B. Two small resistors of equal value or two small lamps
- C. VOM or voltmeter
- D. VOM or ammeter
- E. Switch
- F. Wire to complete circuit

II. Procedure

- A. Construct a parallel resistive circuit according to the schematic below (Figure 1)

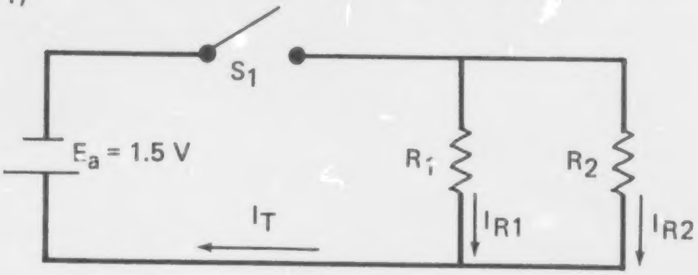


FIGURE 1

- B. Close switch S1
- C. Measure and record applied voltage (E_a)
- D. Measure and record voltage across R_1, and across R_2
- E. Compare recorded voltages. Are they all equal? Explain why
- F. Open switch S1
- G. Connect ammeter in series with R1
- H. Close switch S1 and read and record current (I_{R1})

JOB SHEET #1

I. Open switch S1

J. Disconnect ammeter from R1 branch and connect it in series with R2

K. Close switch S1, and read and record current (I_{R2})

L. Open switch S1

M. Disconnect ammeter from R1 branch, and connect it in series with the voltage source (E_a) and switch S1

N. Close switch S1 and read and record main current (I_T)

O. Open switch S1

P. Are recorded currents I_{R1} and I_{R2} equal? (NOTE: Explain why or why not.)

Q. Add I_{R1} and I_{R2}. Does the sum equal I_T? (NOTE: Explain why or why not.)

R. Close switch; if lamps were used for R1 and R2, note that both lamps are glowing

S. Disconnect R2 from circuit.

T. Record ammeter indication, and, if R1 and R2 are lamps, note any changes in R1 operation when R2 (lamp) was removed

U. Replace R2, and remove R1 from circuit.

V. Record ammeter indication, and note any changes in R2 operation, if applicable

W. Reconnect R1

X. Using voltmeter read and record applied voltage (E_a), E_{R1}, and E_{R2}

Y. Using measured E_a and I_T, compute total resistance of the circuit (R_T)

Z. Using measured voltage and current values, compute R1 and R2, and from these figures compute R_T

AA. If R1 and R2 are lamps, explain changes in lamp operation when one lamp was removed from the circuit

BB. Return meter and materials to proper storage area

PARALLEL CIRCUITS
UNIT XI

JOB SHEET #2--COMPUTE POWER IN A PARALLEL CIRCUIT

I. Equipment and materials needed

- A. Two 1 1/2-volt batteries or equivalent
- B. Three resistors approximately 300 ohms to 500 ohms in value
- C. Switch
- D. VOM or ammeter
- E. VOM or voltmeter

II. Procedure

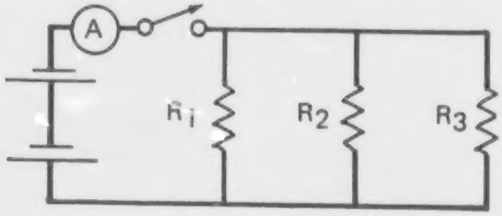


FIGURE 1

- A. Connect the circuit as shown (Figure 1)
- B. Close the switch and record I_T
- C. With the switch closed, read E_a with the voltmeter
- D. Open the switch and insert an ammeter in series with R1
- E. Close the switch and record I_{R1}
- F. Repeat Steps D and E for branches R2 and R3
- G. Disconnect the circuit
- H. Compare I_T (Step B) with the totals of I_{R1}, I_{R2}, and I_{R3} (NOTE: Explain any difference.)
- I. What is the total power furnished by the batteries to the resistors? (P = EI)

JOB SHEET #2

J. Compute the power consumed by each of the resistors R1, R2, and R3, using E_a and the measured branch currents (P=EI)

K. Does the sum of branch power wattage equal power furnished by the battery? (NOTE: Explain why or why not.)

L Return meters and materials to proper storage area

PARALLEL CIRCUITS
UNIT XI

NAME ______________________________

TEST

1. Match the terms on the right with the correct definitions.

_____a. An element or condition which determines the value of circuit variables

_____b. One (1) divided by that number

_____c. Applying Ohm's law and other rules to determine the effect of certain parameters on circuit variables

_____d. An electronic circuit which provides more than one path for current flow

_____e. Changeable or capable of being changed

1. Parallel circuit
2. The reciprocal of a number
3. Variable
4. Parameter
5. Circuit analysis

2. Select true statements regarding the rules governing voltage in a parallel circuit by placing an "X" in the appropriate blanks.

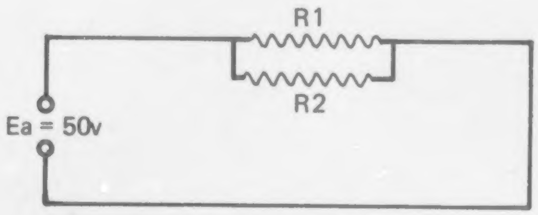
_____a. The sum of the voltages of each branch equals the applied voltage

_____b. In a circuit containing three resistors in parallel, $E_a = E_{R1} = E_{R2} = E_{R3}$, because the voltage is the same across parallel branches

_____c. If Christmas tree lights are connected in parallel, the whole string of lights goes out when any one bulb burns out

_____d. In the circuit below, E_{R1} equals 50 volts

_____e. In the circuit below, E_{R2} is less than 50 volts



3. Select true statements regarding the rules governing current in a parallel circuit by placing an "X" in the appropriate blanks.

______a. In a parallel circuit, the main line current (I_T) equals the sum of all branch currents ($I_1 + I_2 + I_3 \ldots$)

______b. In circuit No. 1, I_T equals 2 amps

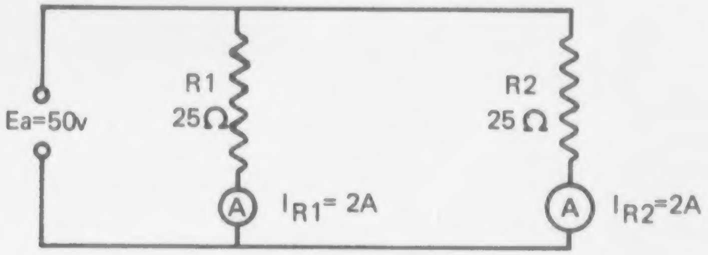
______c. In circuit No. 1, I_T equals 4 amps

______d. In circuit No. 2, I_{R1} equals 2 amps

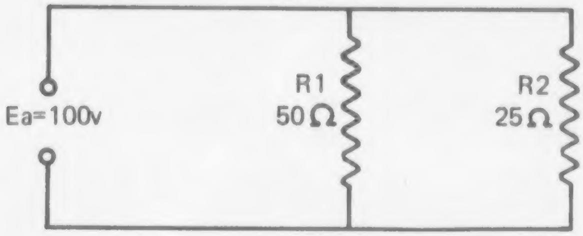
______e. In circuit No. 2, I_{R2} equals 6 amps

______f. In circuit No. 2, I_T equals 6 amps

No. 1

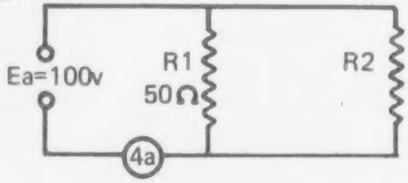

Ea=50v
R1
25Ω
R2
25 Ω
A
I_{R1}= 2A
A
I_{R2}=2A

No. 2

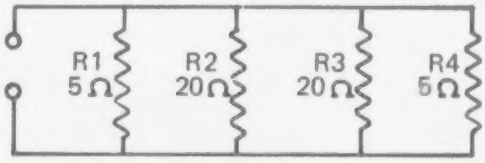

Ea=100v
R1
50Ω
R2
25Ω

4. Determine the formula to use and the total resistance in each of the following resistive parallel circuits:

a.


Ea=100v
R1
50Ω
R2
4a

b.


R1
5Ω
R2
20Ω
R3
20Ω
R4
5Ω

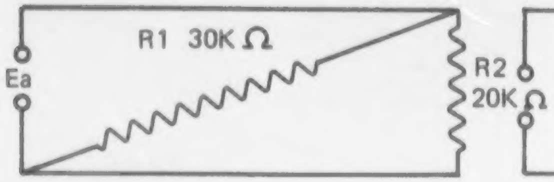
1. Formula = ____________

2. R_T = ________________

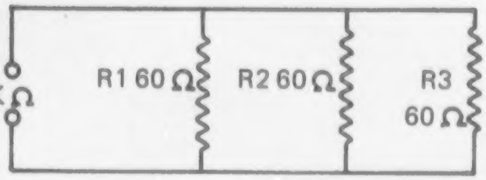
1. Formula = ____________

2. R_T = ________________

c.


R1 30K Ω
Ea
R2
20K Ω

d.


R1 60 Ω
R2 60 Ω
R3
60 Ω

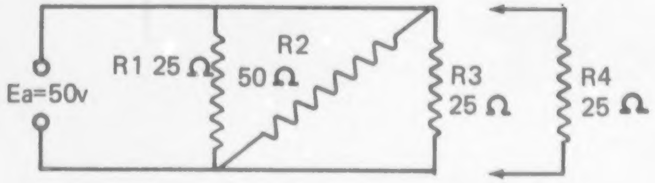
1. Formula = ____________

2. R_T = ________________

1. Formula = ____________

2. R_T = ________________

5. Perform a circuit analysis of the parallel circuit below by inserting proper arrow symbols in the blank squares:


Ea=50v
R1 25 Ω
R2
50 Ω
R3
25 Ω
R4
25 Ω

Ea		▨											
Add R4													
R1								▨					
	I_T	E_A	R_T	P_T	I_{R1}	I_{R2}	I_{R3}	R1	R2	R3	E_{R1}	E_{R2}	E_{R3}

6. Select true statements regarding the effects of opens and shorts in parallel circuits by placing an "X" in the appropriate blanks.

    _____a. An open in the main line of a parallel circuit before the first component prevents current flow through the entire circuit

    _____b. An open in a branch of a parallel circuit prevents current flow through the entire circuit

    _____c. A direct short across a parallel circuit shunts the total current through the short and away from all branches

    _____d. A short has no effect upon the current in a parallel circuit

7. Demonstrate the ability to:

    a. Measure voltage, current, and resistance in a parallel circuit

    b. Measure power in a parallel circuit

    (NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

PARALLEL CIRCUITS
UNIT XI

ANSWERS TO TEST

1. a. 4
   b. 2
   c. 5
   d. 1
   e. 3

2. b, d

3. a, c, d, f

4. a. 1) $R = \frac{E}{I}$ 2) 25Ω

   b. 1) $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}$

      2) 2Ω

   c. 1) $R_T = \frac{R1 \times R2}{R1 + R2}$ 2) 12KΩ

   d. 1) $R_T = \frac{R}{N}$ 2) 20Ω

5.

Ea ↑	↑	▨	→	↑	↑	↑	↑	→	→	→	↑	↑	↑
Add R4	↑	→	↓	↑	→	→	→	→	→	→	→	→	→
R1	↓	→	↑	↓	↓	→	→	▨	→	→	→	→	→
	I_T	E_A	R_T	P_T	I_{R1}	I_{R2}	I_{R3}	R1	R2	R3	E_{R1}	ER2	E_{R3}

6. a, c

7. Performance skills evaluated to the satisfaction of the instructor.

SERIES-PARALLEL CIRCUITS
UNIT XII

UNIT OBJECTIVE

After completion of this unit, the student should be able to arrange in proper order the steps to simplify a series-parallel circuit, and select true statements describing the function of ground as a voltage reference and the functions of a voltage divider. The student should also be able to measure and calculate quantities in series-parallel circuits and construct a voltage divider and analyze its function. This knowledge will be evidenced by correctly performing the procedures outlined on the assignment and job sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms associated with series-parallel circuits with their correct definitions.
2. Match schematic symbols for grounds with their correct definitions.
3. State Kirchhoff's current law.
4. Arrange in proper order the steps to simplify a series-parallel circuit.
5. Select true statements describing the function of ground as a voltage reference.
6. Select true statements describing the functions of a voltage divider.
7. Demonstrate the ability to:
    a. Measure and calculate quantities in series-parallel circuits.
    b. Construct a voltage divider and analyze its function.

SERIES-PARALLEL CIRCUITS
UNIT XII

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information, assignment, and job sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information and assignment sheets.

VI. Demonstrate and discuss procedures outlined in the job sheets.

VII. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

  A. Objective sheet

  B. Information sheet

  C. Transparency masters

    1. TM 1--Series-Parallel Circuit
    2. TM 2--Steps to Simplify a Series-Parallel Circuit
    3. TM 3--Series-Parallel Circuit and Equivalent Circuit
    4. TM 4--Circuit Reduction
    5. TM 5--Voltage Divider

  D. Assignment sheets

    1. Assignment Sheet #1--Trace Current Flow in Series-Parallel Circuits
    2. Assignment Sheet #2--Perform Exercises in Circuit Reduction
    3. Assignment Sheet #3--Solve for Total Resistance
    4. Assignment Sheet #4--Solve for Total Current

5. Assignment Sheet #5--Solve for Total Voltage

6. Assignment Sheet #6--Solve for Total Power in Series-Parallel Circuits

7. Assignment Sheet #7--Solve for Branch Voltages and Currents in Series-Parallel Circuits

8. Assignment Sheet #8--Solve for Multiple Values of Voltage and Current

9. Assignment Sheet #9--Answer Questions Regarding Opens and Shorts in Series-Parallel Circuits

10. Assignment Sheet #10--Answer Questions about Grounds and Voltage Polarity

11. Assignment Sheet #11--Analyze No-Load and Load Circuits

E. Answers to Assignment Sheets

F. Job sheets

1. Job Sheet #1--Measure and Calculate Quantities in Series-Parallel Circuits

2. Job Sheet #2--Construct a Voltage Divider and Analyze its Function

G. Test

H. Answers to test

II. References

A. Grob, Bernard. *Basic Electronics.* New York: McGraw-Hill, 1977.

B. Marcus, Abraham and Samuel E. Gendler. *Basic Electronics.* Englewood Cliffs, NJ: Prentice-Hall, 1971.

SERIES-PARALLEL CIRCUITS
UNIT XII

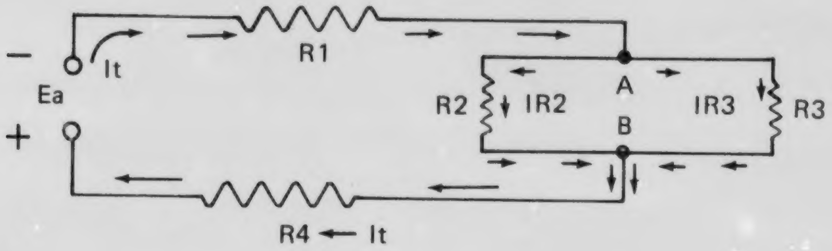
INFORMATION SHEET

I. Terms and definitions

A. Series-parallel circuit--A circuit which contains some components in series and others in parallel (Transparency 1)

B. Node--A junction point in a circuit at which current divides into separate parallel branches, or reunites from parallel branches

Example: In the series-parallel circuit below, points A and B are the nodes



C. Circuit reduction--Simplifying a circuit by combining elements

D. Ground--A voltage reference point which may indicate a current return path to one side of the voltage source

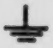
(NOTE: A ground is not always connected to earth or to one side of the power source.)

E. Earth ground--Connection of one side of the voltage or current source to conductive metal which enters the earth at some point

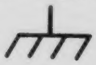
F. Chassis ground--Connection of one side of the voltage or current source to the metal frame of the equipment

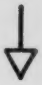
G. Voltage divider--A system of resistors connected across a voltage source to permit the tapping of voltages of different values

II. Schematic symbols for grounds

A. Earth ground-- 

(NOTE: Sometimes earth and chassis ground symbols are interchanged.)

B. Chassis ground-- 

C. Common ground (voltage reference point or current return)-- 

INFORMATION SHEET

III. Kirchhoff's current law--The sum of all the currents flowing into a point or junction (node) in a circuit is equal to the sum of all the currents flowing away from that point or junction (node)

(NOTE: If 1 amp flows into a junction, 1 amp must flow away from that junction, whether in a single path or in many paths. In other words, current cannot accumulate anywhere in a circuit.)

IV. Steps to simplify a series-parallel circuit (Transparencies 2, 3 and 4)

A. Trace current flow and indicate polarity

1. Begin at negative side of supply and move toward positive side

2. Identify polarity of voltage drops of components as current is traced

B. Identify nodes (where current divides and where current reunites)

C. Identify series resistors

D. Identify series or parallel groups of resistors

E. Reduce each parallel group to an equivalent resistance, R_{eq}

F. Redraw the circuit using a single resistor to represent each equivalent resistance

G. Combine all equivalent resistances and series resistances to determine total resistance

H. Determine total current by dividing applied voltage by total resistance

V. Function of ground as a voltage reference (Transparency 5)

A. Any type of ground may be used

B. Use of grounds helps simplify the schematic

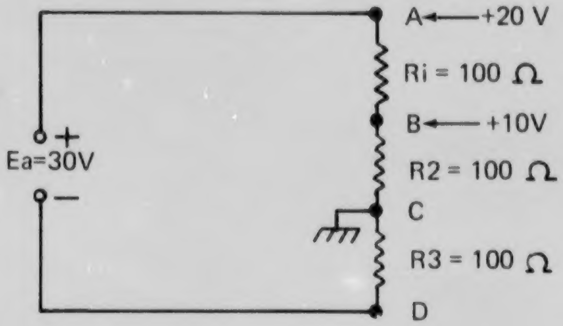
C. Ground may be the common return path for current (usually the chassis)

D. Chassis ground permits use of the chassis for the voltage reference point for all voltage measurements

INFORMATION SHEET

E. A ground permits the generation of both positive and negative voltages

Example: In the circuit below, the chassis is grounded at point C which permits positive voltages to be obtained at points A and B and a negative voltage to be obtained at point D



VI. Functions of a voltage divider

A. A voltage divider allows tapping off of different voltages for various applications

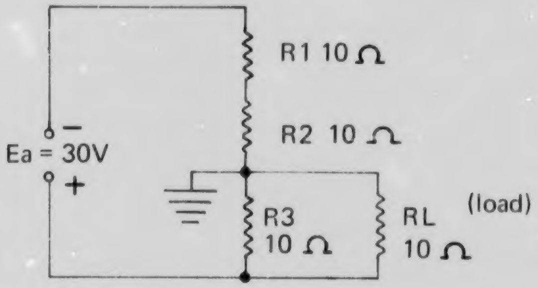
B. Chassis ground is often used as the zero reference point

C. Tapped voltages may be either positive or negative

D. A load is connected in parallel with the resistor from which the voltage is tapped

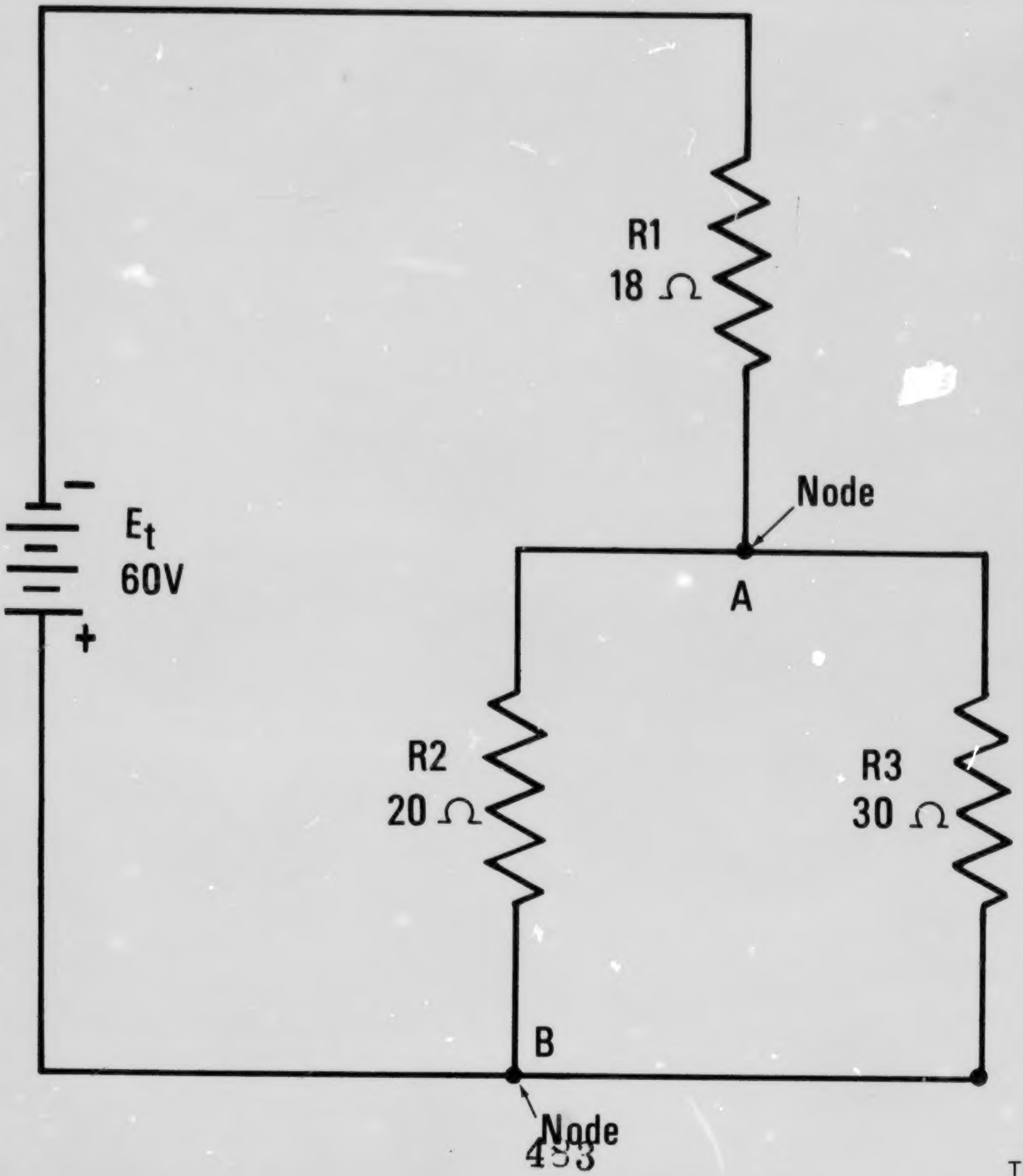
E. If the load draws appreciable current, the voltage division differs from the no-load condition

Example: In the circuit below, the chassis is grounded at the point between R2 and R3. The equivalent resistance (R_{eq}) of R3 and R_L is 5 ohms. The total resistance across the applied voltage is 25 ohms. The open load voltage across R3 is 10 volts but the load voltage (with R_L connected) is 6 volts.

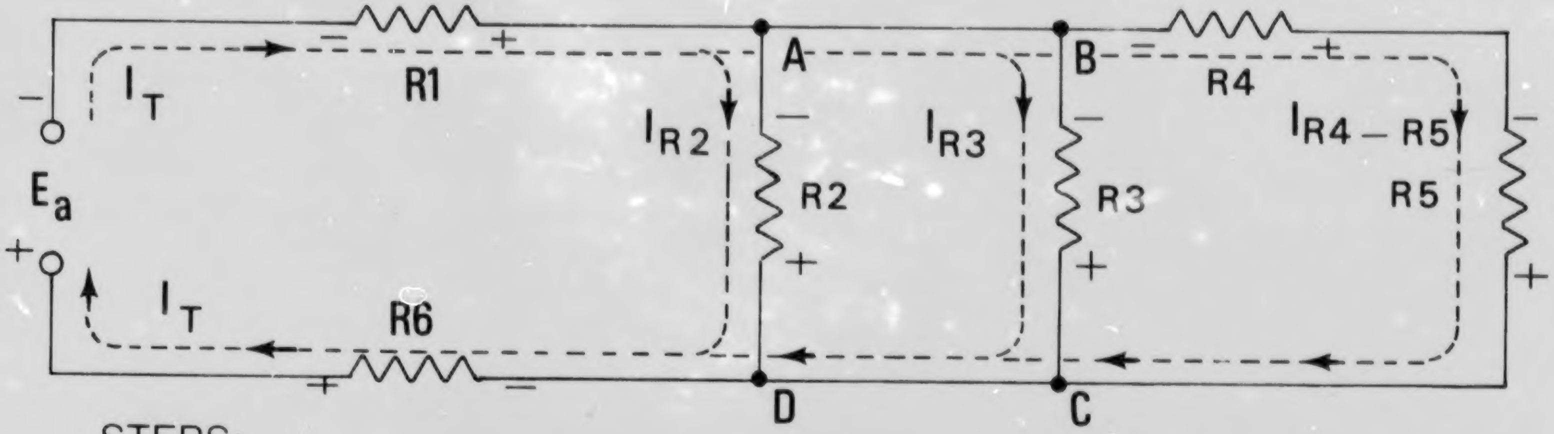


Series-Parallel Circuit

R1 is in Series with the Parallel Branches R2–R3


R1
18 Ω
Node
A
E_t
60V
−
+
R2
20 Ω
R3
30 Ω
B
Node

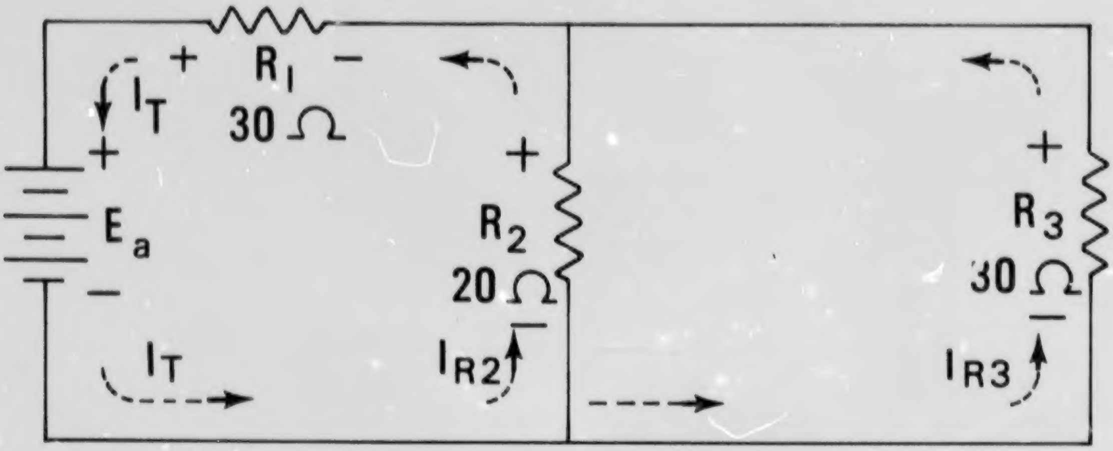
Steps to Simplify a Series-Parallel Circuit



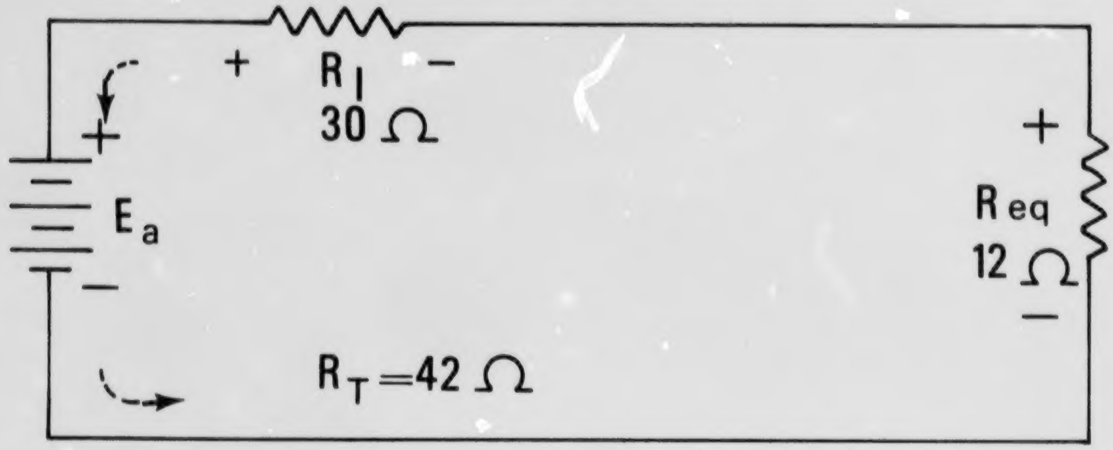
STEPS:

1. Trace Current Flow and Identify Voltage Drop Polarity (See Above)
2. Identify Nodes
    a. Current Division — A & B
    b. Current Return — C & D
3. Identify Resistors in Series With Ea: R1 & R6
4. Identify Resistors in Parallel: R2, R3, & (R4 + R5)
5. Identify Series-Parallel Resistors:
    a. R2, R3, & (R4 + R5) Become R_{eq} When the Reciprocal Resistance Formula is Applied
    b. R1 & R6 are in Series with R_{eq}
6. Determine Total Resistance: RT = R1 + R_{eq} + R6

Series-Parallel Circuit and Equivalent Circuit

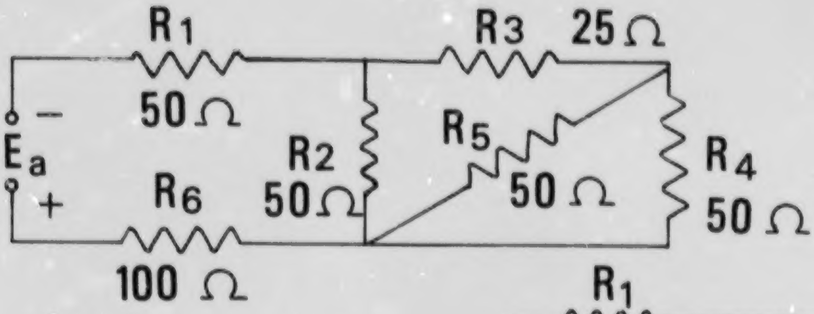

I_T
+ R_1 −
30 Ω
+
E_a
−
+
R_2
20 Ω
−
I_{R2}
+
R_3
30 Ω
−
I_{R3}
I_T

Circuit

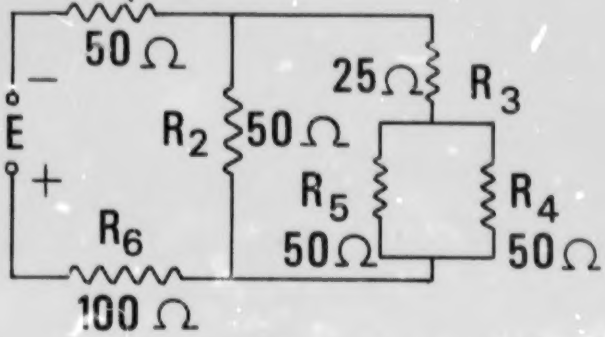

+ R_1 −
30 Ω
+
E_a
−
+
R_{eq}
12 Ω
−
R_T =42 Ω

Equivalent Circuit

Circuit Reduction

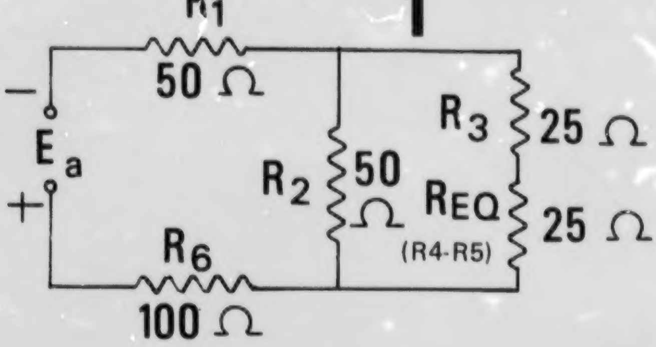

R1
50 Ω
R3 25 Ω
Ea
−
+
R2
50 Ω
R5
50 Ω
R4
50 Ω
R6
100 Ω

Step A: Trace Current Flow
and Re-Draw Circuit

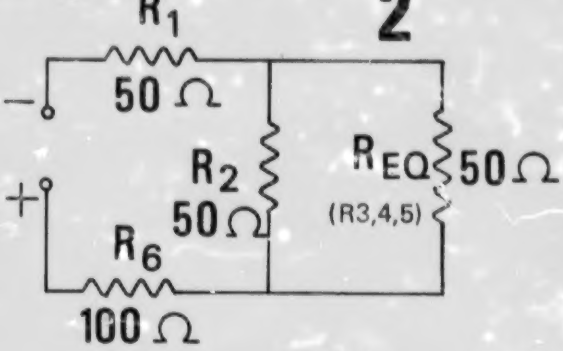

R1
50 Ω
E
−
+
R2
50 Ω
25 Ω
R3
R5
50 Ω
R4
50 Ω
R6
100 Ω

Step B: Reduce Circuit

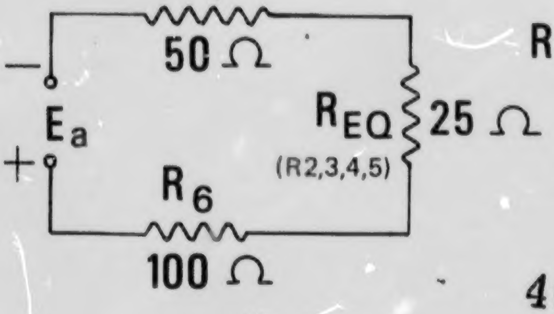
1


R1
50 Ω
Ea
−
+
R2
50 Ω
R3
25 Ω
REQ
(R4-R5)
25 Ω
R6
100 Ω

2

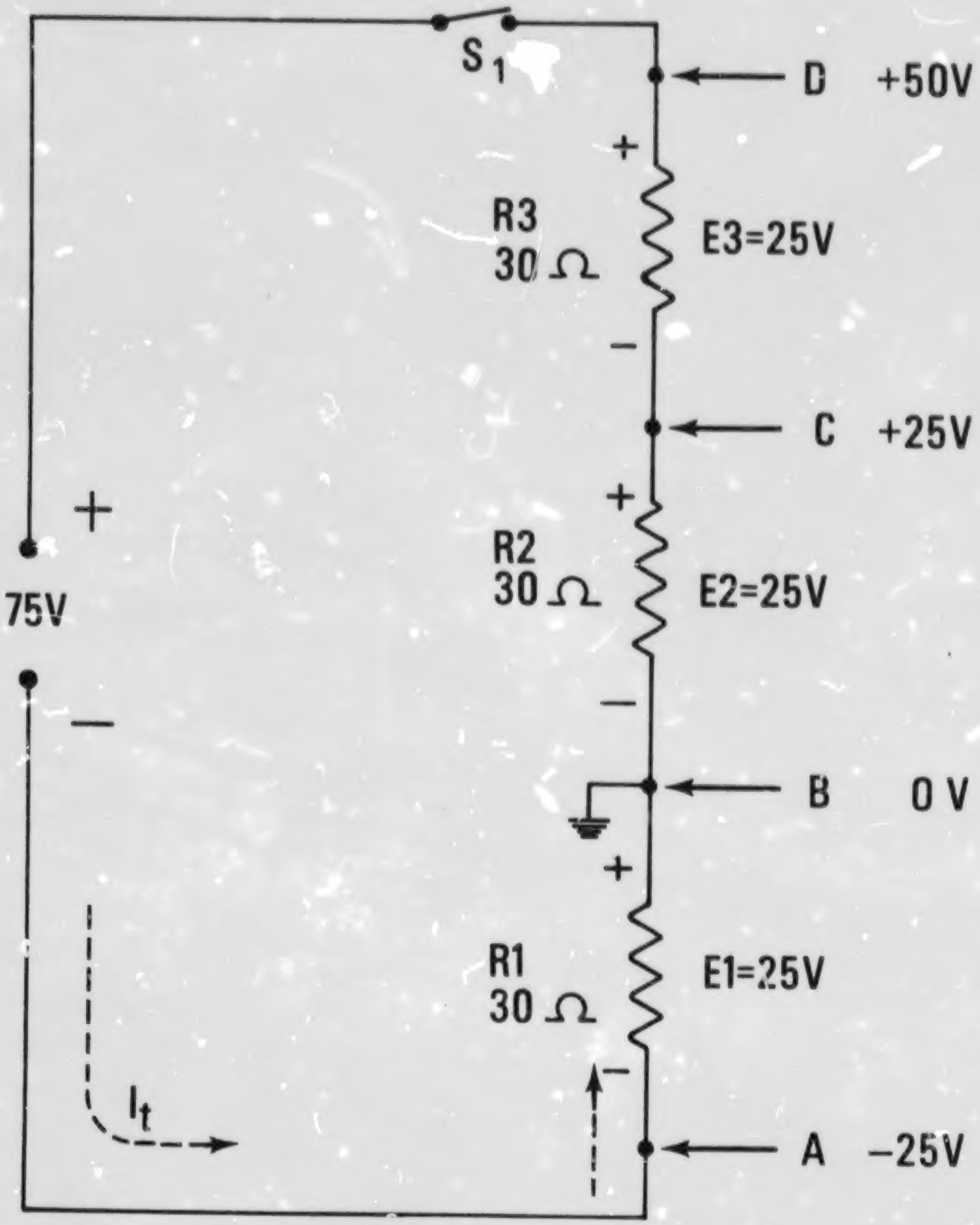

R1
50 Ω
−
+
R2
50 Ω
REQ
(R3,4,5)
50 Ω
R6
100 Ω

3


R1
50 Ω
Ea
−
+
REQ
(R2,3,4,5)
25 Ω
R6
100 Ω

$R_T = R_1 + R_{EQ} + R_6 = 175\ \Omega$

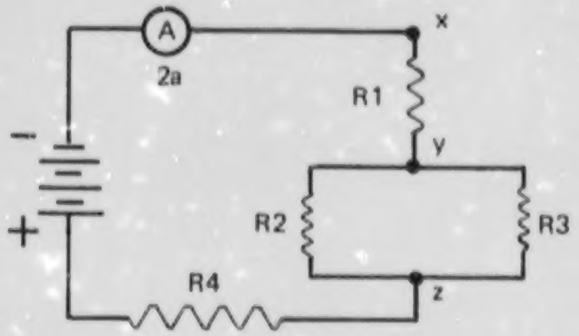
Voltage Divider


S1
D +50V
+
R3
30 Ω
E3=25V
−
C +25V
+
75V
−
+
R2
30 Ω
E2=25V
−
B 0 V
+
R1
30 Ω
E1=25V
−
It
A −25V

SERIES-PARALLEL CIRCUITS
UNIT XII

ASSIGNMENT SHEET #1--TRACE CURRENT FLOW IN SERIES-PARALLEL CIRCUITS

1. Study the schematic and complete the statement below it.



Current will divide at Point_____, and come back together at Point_____.

2. From the circuit above, list the resistors:

in series____________.

in parallel___________.

3. In the circuit above, Resistors 2 and 3, (check the correct statement)

_____a. will carry a combined two amps of current

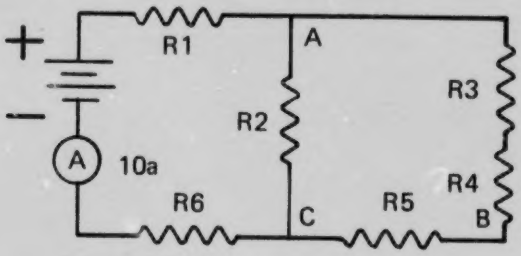
_____b. will each carry two amps of current

_____c. will carry a combined one amp of current

_____d. will each carry less than two amps of current

ASSIGNMENT SHEET #1

4. Study the schematic below and complete the questions below it.



a. At what point does current divide?

b. At what point does it come back together?

c. Does current divide more than once?

5. List the three resistors in the circuit above that form a series string.

a.

b.

c.

6. List the resistors in the circuit above in series with the source.

7. In the circuit (4), which statements below are correct?

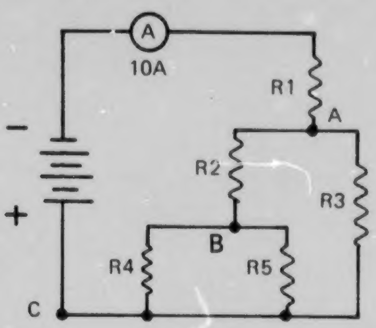
______a. R2 is in parallel with R3, R4, and R5

______b. Less than 10 amps will flow through R2

______c. 10 amps will flow through R6

______d. Less than 10 amps will flow through R3, R4, R5

8. Study the following schematic and answer the questions below it.



a. At what point does current first divide?

b. At what point does current next divide?

c. At what point does current all come back together?

9. In the circuit (8) check the pairs of resistors that are in parallel with each other.

______a. R1 and R3

______b. R2 and R4

______c. R2 and R5

______d. R4 and R5

10. Answer these questions (Circuit 8)

a. How many resistors are directly in series with the rest of the circuit?

b. Is the R_{eq} of R4 and R5 in series with R2?

11. Check the statements that are correct. (Circuit 8)

______a. $I_{R2} + I_{R3} = 10$ amps

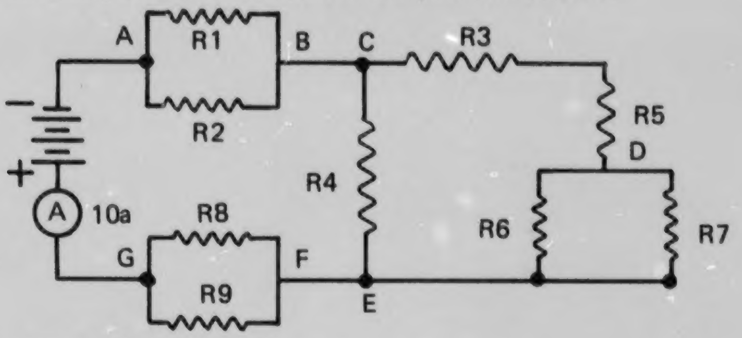
______b. An ammeter at Point C will measure 10 amps

______c. Current through R5 will be more than through R1

______d. $I_{R4} + I_{R5} = I_{R2}$

ASSIGNMENT SHEET #1

12. Study the following schematic and answer the questions below it.



a. Current first divides at which point?

b. Current next divides at which point?

c. Does current also divide at Point D? Point F?

d. How many resistors are in series with the source?

e. Will there be a full 10 amps of current through R7?

f. Will there be a full 10 amps of current through R4?

g. Will there be a full 10 amps of current at Point G?

h. Does total current go through R2?

i. Does a full 10 amps enter R9?

j. Will current be common through R3 and R5?

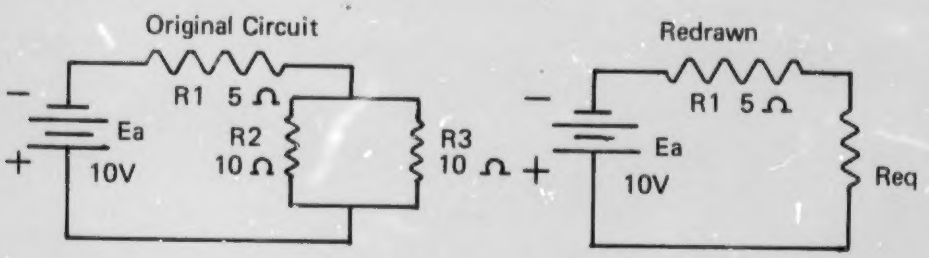
k. Does the full 10 amps of current enter Point D?

l. Name the two resistors in string.

SERIES-PARALLEL CIRCUITS
UNIT XII

ASSIGNMENT SHEET #2--PERFORM EXERCISES IN CIRCUIT REDUCTION

1. This assignment is to reduce series-parallel circuits by re-drawing them as series circuits, in this manner:

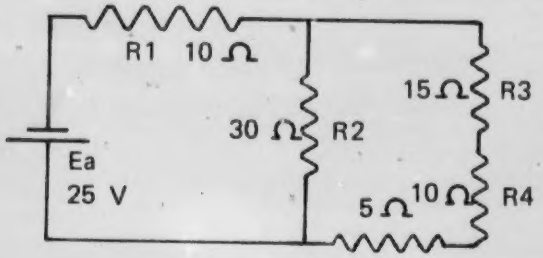

Original Circuit
Redrawn
R1 5 Ω
Ea
10V
R2
10 Ω
R3
10 Ω
R1 5 Ω
Ea
10V
Req

R2 and R3 in the original circuit have been combined into one resistor, which has become R_{eq} in the redrawn circuit. R_{eq} in the redrawn circuit will have the same resistance as R2 and R3 combined in the original circuit. In other words, R_{eq} in the redrawn circuit will be equal to R_{eq} of the original circuit.

a. What is the resistance value of R_{eq} in the redrawn circuit above?

b. Redraw the series-parallel circuit with just one resistor and show its value.

2. Redraw the circuit below by combining R3, R4, and R5. Show the new value.


R1 10 Ω
15 Ω R3
30 Ω R2
Ea
25 V
5 Ω
10 Ω R4

ASSIGNMENT SHEET #2

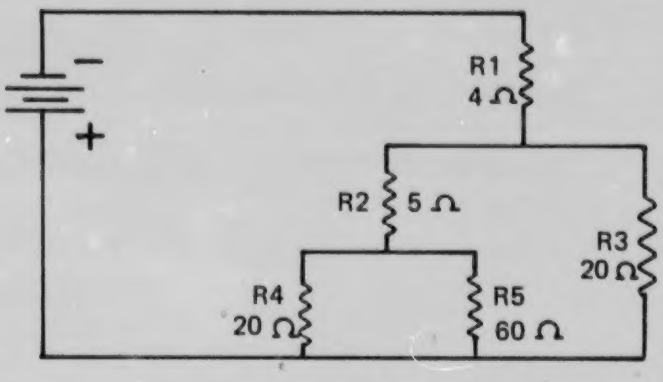
3. You should now have two resistors in parallel. Redraw the circuit again, combining the parallel branches. Show the equivalent value of the parallel branch.

4. Your circuit should now be a series circuit with two resistors. Redraw the circuit once more, showing one equivalent resistor. Show values, including I_T, on the schematic.

SERIES-PARALLEL CIRCUITS
UNIT XII

ASSIGNMENT SHEET #3--SOLVE FOR TOTAL RESISTANCE

1. This assignment will combine circuit reductions and solve for total circuit resistance in more complex circuits. Use the steps cited in the Information Sheet and refer to it if necessary. Study the circuit below. Trace current flow and determine which resistors are in parallel.



a. First, find R_{eq} for R4 and R5 = ________________

b. Redraw circuit, showing R4 and R5 combined into one equivalent resistor. Show values.

2. Note that R2 and R_{eq} are now in series and are additive. Combine R2 and R_{eq} into one equivalent resistor, R_{eq}. Redraw the circuit and show values.

ASSIGNMENT SHEET #3

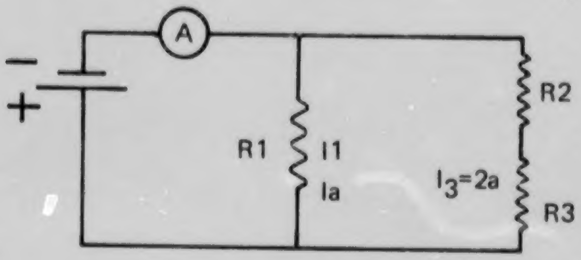
3. Notice now that the new R_{eq} is in parallel with R3. Find the next R_{eq} and redraw the circuit with appropriate values shown.

4. Redraw the final circuit showing one equivalent resistor, R_T.

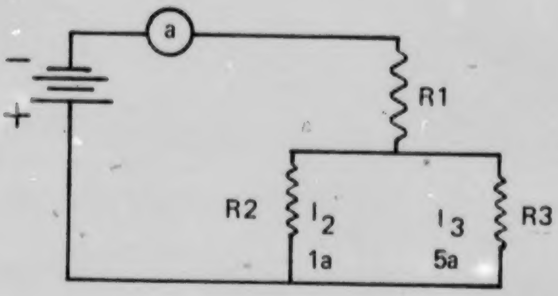
SERIES-PARALLEL CIRCUITS
UNIT XII

ASSIGNMENT SHEET #4--SOLVE FOR TOTAL CURRENT

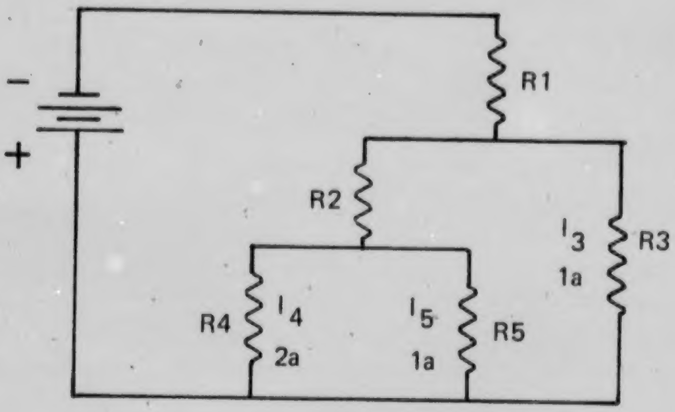
1. Study the circuit below. I_T = ____________.


A
−
+
R1
I1
Ia
I_3=2a
R2
R3

2. Find I_T = ____________.


a
−
+
R1
R2
I_2
1a
I_3
5a
R3

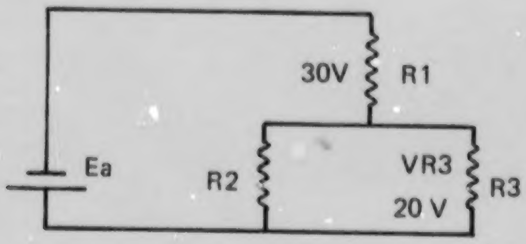
3. Find I_T = ____________.


−
+
R1
R2
I_3
1a
R3
R4
I_4
2a
I_5
1a
R5

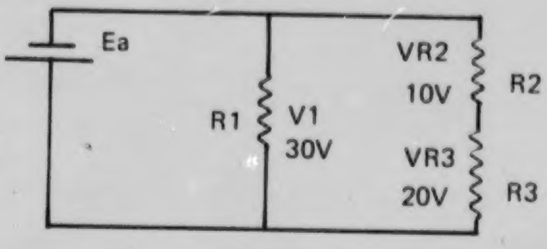
SERIES-PARALLEL CIRCUITS
UNIT XII

ASSIGNMENT SHEET #5--SOLVE FOR TOTAL VOLTAGE

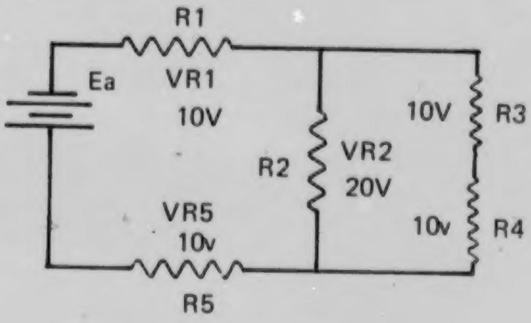
1. Find E_a. E_a = ______________________________


30V
R1
Ea
R2
VR3
20 V
R3

2. Find E_a. E_a = ______________________________


Ea
VR2
10V
R2
R1
V1
30V
VR3
20V
R3

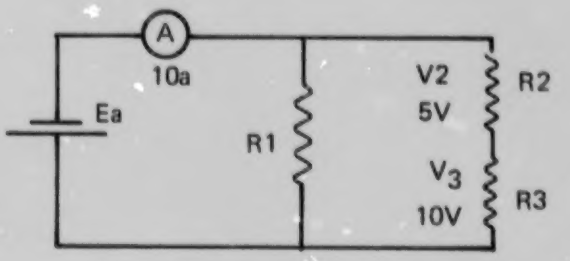
3. Find E_a. E_a = ______________________________


R1
Ea
VR1
10V
10V
R3
R2
VR2
20V
VR5
10v
10v
R4
R5

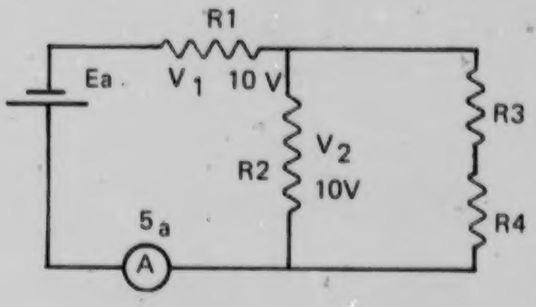
SERIES-PARALLEL CIRCUITS
UNIT XII

ASSIGNMENT SHEET #6--SOLVE FOR TOTAL POWER IN SERIES-PARALLEL CIRCUITS

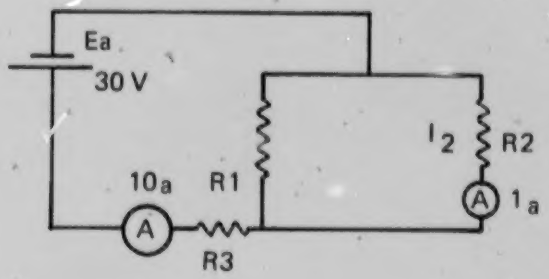
1. Find P_T. P_T = ____________________


A
10a
Ea
R1
V2
5V
R2
V_3
10V
R3

2. Find P_T. P_T = ____________________


R1
Ea
V_1 10 V
R3
R2
V_2
10V
R4
5_a
A

3. Find P_T. P_T = ____________________

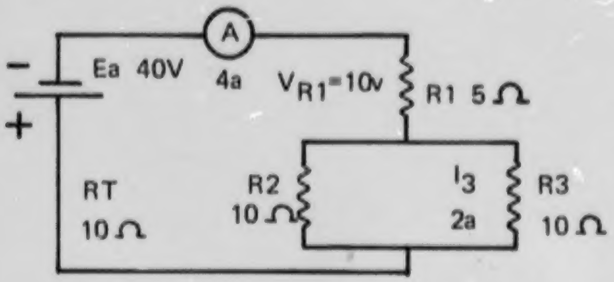

Ea
30 V
I_2
R2
10a
R1
A
1_a
A
R3

SERIES-PARALLEL CIRCUITS
UNIT XII

ASSIGNMENT SHEET #7--SOLVE FOR BRANCH VOLTAGES AND CURRENTS IN SERIES-PARALLEL CIRCUITS

1. In this assignment, you will solve for branch voltage drop and current through branches.

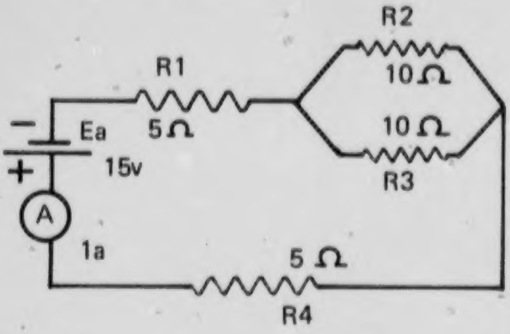
   a. In the schematic below V_{R3} = ______________________________.


A
Ea 40V
4a
V_{R1}=10v
R1 5 Ω
−
+
RT
10 Ω
R2
10 Ω
I_3
2a
R3
10 Ω

   b. What is V_{R2}? ______________________________

   c. Find I_{R2} above ______________________________

2. In the circuit below, the voltage drop across R_4 is ______________________________.


R2
10 Ω
R1
10 Ω
Ea
5 Ω
15v
R3
A
1a
5 Ω
R4
−
+

3. In the circuit above, V_{R2} = ______________________________

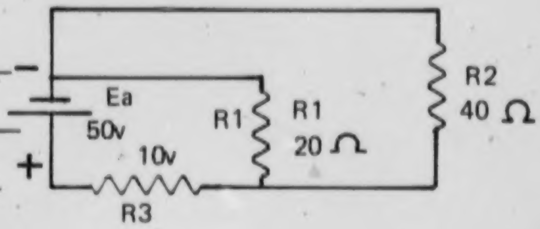
4. In the circuit above I_{R3} = ______________________________

5. Study this circuit.

   a. Find V_{R2} ______________________________

   b. Find I_{R1} ______________________________

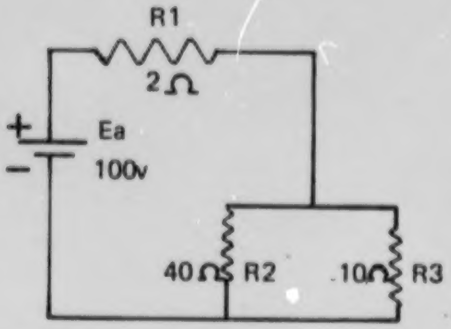
   c. Find I_{R2} ______________________________


−
Ea
50v
+
10v
R1
R1
20 Ω
R2
40 Ω
R3

SERIES-PARALLEL CIRCUITS
UNIT XII

ASSIGNMENT SHEET #8--SOLVE FOR MULTIPLE VALUES OF VOLTAGES AND CURRENT

1. Solve for quantities indicated.


R1
2 Ω
+
−
Ea
100v
40 Ω
R2
10 Ω
R3

a. R_{eq} of R2, R3 = __________

b. R_T = __________

c. I_T = __________

d. V_{R1} = __________

e. V_{R2} = __________

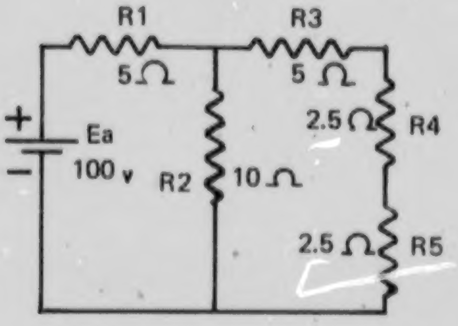
f. V_{R3} = __________

g. I_{R1} = __________

h. I_{R2} = __________

i. I_{R3} = __________

2. Solve for quantities indicated.


R1
5 Ω
R3
5 Ω
+
−
Ea
100 v
R2
10 Ω
2.5 Ω
R4
2.5 Ω
R5

a. R_T = __________

b. I_T = __________

c. V_{R1} = __________

d. V_{R2} = __________

e. V_{R3} = __________

f. V_{R4} = __________

g. V_{R5} = __________

h. I_{R2} = __________

i. I_{R3} = __________

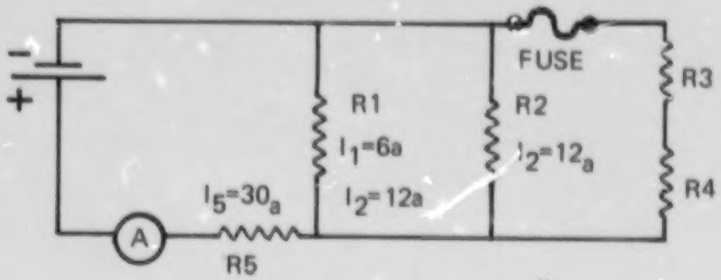
j. I_{R4} = __________

k. I_{R5} = __________

SERIES-PARALLEL CIRCUITS
UNIT XII

ASSIGNMENT SHEET #9--ANSWER QUESTIONS REGARDING OPENS AND SHORTS IN SERIES-PARALLEL CIRCUITS

1. The fuse in the circuit below is rated at 10 amps. Analyze the circuit and answer the questions below it.

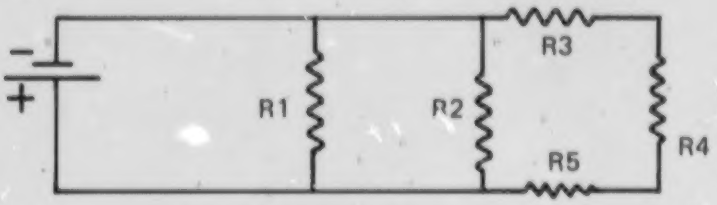


−
+
FUSE
R3
R1
I_1=6a
R2
I_2=12a
I_5=30a
I_2=12a
R4
A
R5

   a. How many amps will try to flow through the fuse?

   b. Will the fuse blow and create an open?

2. In the following circuit an open suddenly occurs between R3 and R4. Answer the questions.



−
+
R3
R1
R2
R5
R4

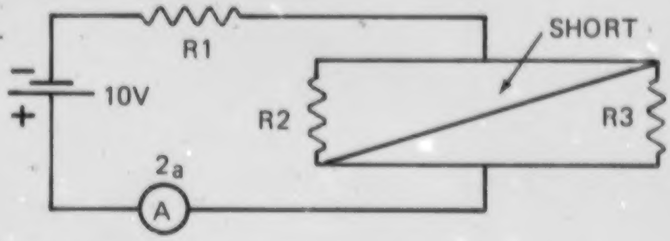
   a. Total current will (increase, decrease, stay the same)____________________.

   b. I_{R3} will (increase, decrease, stay the same)____________________.

3. In the shorted circuit below, the current flowing through

   a. R2 = ____________________

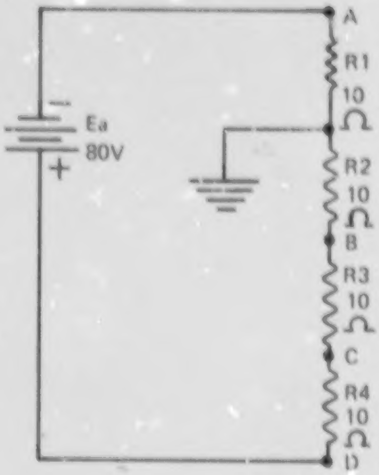
   b. R3 = ____________________



SHORT
R1
−
+
10V
R2
R3
2a
A

SERIES-PARALLEL CIRCUITS
UNIT XII

ASSIGNMENT SHEET #10--ANSWER QUESTIONS ABOUT GROUNDS AND VOLTAGE POLARITY



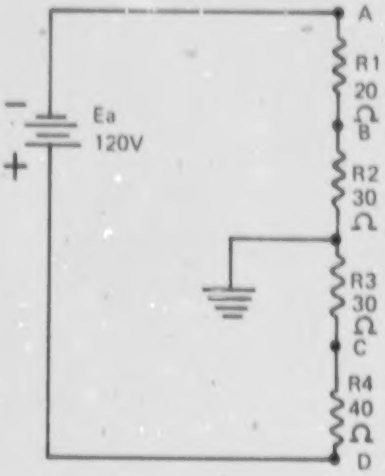
1. This assignment deals with voltage dividers and grounds, especially with grounds not located at the power source. Study the circuit and indicate the polarity and voltages requested.

   a. The voltage between Point A and ground is______________(positive/negative)

   b. The voltage polarity between Point B and ground is______________(positive/negative)

   c. The voltage polarity between Point C and ground is______________(positive/negative)

   d. The voltage polarity between Point D and ground is______________(positive/negative)



2. Study the circuit and answer the questions.

   a. The voltage and polarity from Point A to ground is ______________________________

   b. V_B (from Point B to ground) is______________

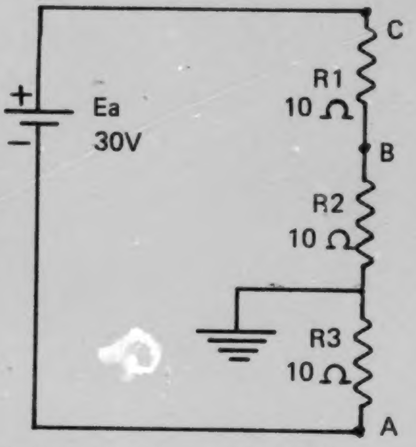
   c. V_C (Point C to ground) is______________

   d. V_D (Point D to ground) is______________

   e. Voltage at Point D with respect to Point A is ______________________________

SERIES-PARALLEL CIRCUITS
UNIT XII

ASSIGNMENT SHEET #11--ANALYZE NO-LOAD AND LOAD CIRCUITS


+
–
Ea
30V
C
R1
10 Ω
B
R2
10 Ω
R3
10 Ω
A

1. In this assignment, you are going to perform a circuit analysis between a no-load circuit and a load circuit. Suppose we have a given circuit with no-load condition.

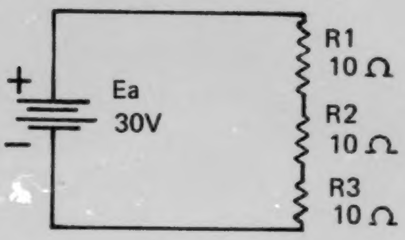
   With respect to ground, what is the polarity and voltage at:

   a. Point A ____________

   b. Point B ____________

   c. Point C ____________

2. First, let us record the quantities in the circuit with no-load or ground connected. Fill in the blanks with the proper values.


+
–
Ea
30V
R1
10 Ω
R2
10 Ω
R3
10 Ω

   a. R_T ____________

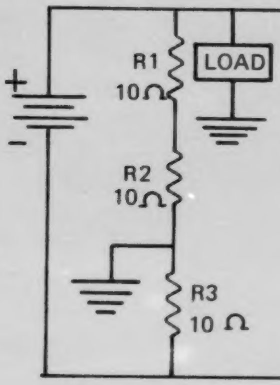
   b. I_T ____________

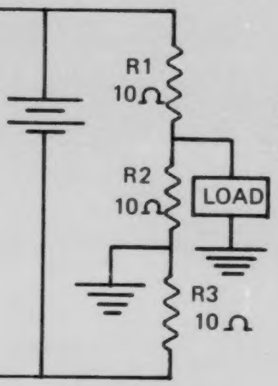
   c. V_{R1} ____________

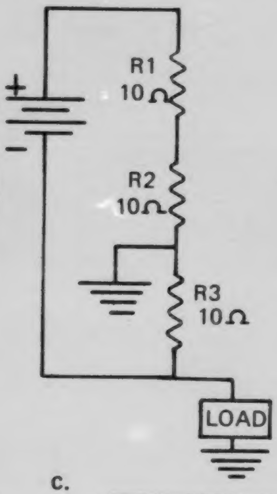
   d. V_{R2} ____________

   e. V_{R3} ____________

3. Suppose now that we want to connect a load that needs negative volts to operate. Which of the following circuits shows the proper load connection?


+
–
R1
10 Ω
LOAD
R2
10 Ω
R3
10 Ω

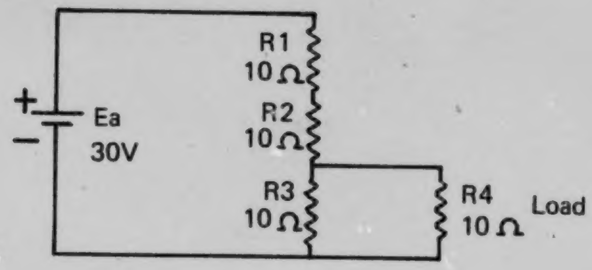

R1
10 Ω
R2
10 Ω
LOAD
R3
10 Ω


+
–
R1
10 Ω
R2
10 Ω
R3
10 Ω
LOAD

a. ____________ b. ____________ c. ____________

ASSIGNMENT SHEET #11

4. Connecting a load to the voltage divider gives a series-parallel circuit, like this:



The important thing to notice here is that R3 now becomes a resistor in parallel instead of in series.

The load we want to operate needs 10 volts. (Do we still have the necessary 10 volts when we connect the load across R3?) By adding the load, we know that many quantities are going to change. Solve for quantities indicated.

a. R_{eq} _____ (R3 and R4)

b. R_T _____

c. I_T _____

d. V_{R1} _____

e. V_{R2} _____

f. V_{R3} _____

5. Compare the quantities in your no-load circuit with the quantities in your load circuit, and complete the boxes below, using arrows to show increases or decreases.

	R_T	I_T	E_{R1}	E_{R2}	E_{R3}
Add R4					

6. State the voltage drop across R4.

7. Will the load have 10 volts, connected as shown above?

SERIES-PARALLEL CIRCUITS
UNIT XII

ANSWERS TO ASSIGNMENT SHEETS

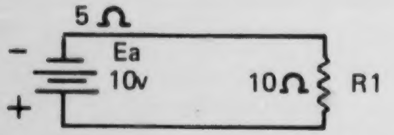
Assignment Sheet #1

1. Point Y, Point Z
2. In series-R1 and R4

   In parallel-R2 and R3
3. a and d
4. a. Point C
   b. Point A
   c. No
5. R3, R4, R5
6. R1, R6
7. All are correct
8. a. Point A
   b. Point B
   c. Point C
9. d
10. a. One (R1)
    b. Yes
11. a, b, d
12. a. Point A
    b. Point C
    c. Yes, Yes
    d. None
    e. No
    f. No
    g. Yes
    h. No
    i. No
    j. Yes
    k. No
    l. R3 and R5

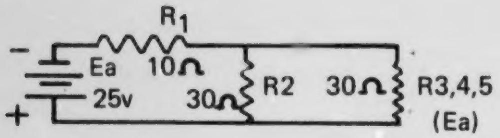
Assignment Sheet #2

1. a.

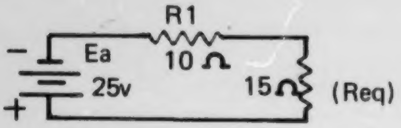

5 Ω
−
Ea
10v
+
10Ω
R1

b.

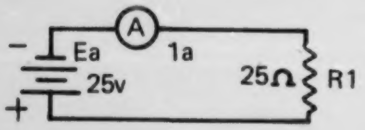
2.


R1
−
Ea
10Ω
25v
+
30Ω
R2
30Ω
R3,4,5
(Ea)

3.


R1
−
Ea
10 Ω
25v
+
15Ω
(Req)

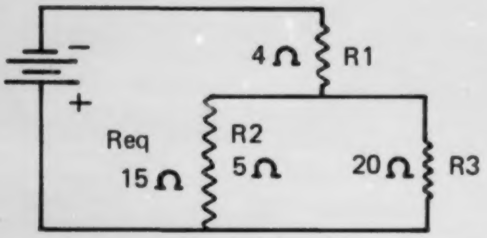
4.


A
−
Ea
1a
25v
+
25Ω
R1

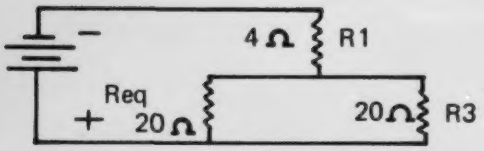
Assignment Sheet #3

1. a. 15 ohms

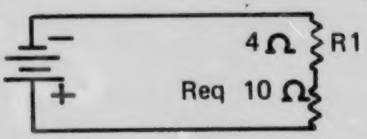
b.


−
+
4 Ω
R1
Req
15 Ω
R2
5 Ω
20 Ω
R3

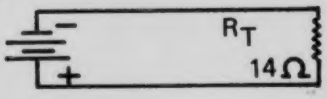
2.


−
4 Ω
R1
Req
+
20 Ω
20Ω
R3

3.


−
+
4 Ω
R1
Req 10 Ω

4.



Assignment Sheet #4

1. 3a
2. 6a
3. 4a

Assignment Sheet 5

1. 50 v
2. 30 v
3. 40 v

Assignment Sheet #6

1. 150w
2. 100w
3. 300w

Assignment Sheet #7

1. a. 20v
   b. 20 v
   c. 2a
2. 5v

3. 5v
4. 0.5a or 500ma
5. a. 40 v
    - b. 2a
    - c. 1a

Assignment Sheet #8

1. a. 8
    - b. 10
    - c. 10a
    - d. 20v
    - e. 80v
    - f. 80v
    - g. 10a
    - h. 2a
    - i. 8a
2. a. 10
    - b. 10a
    - c. 50v
    - d. 50v
    - e. 25v
    - f. 12.5v
    - g. 12.5v
    - h. 5a
    - i. 5a
    - j. 5a
    - k. 5a

Assignment Sheet #9

1. a. 12a
    - b. Yes
2. a. Decrease
    - b. Decrease
3. a. Zero
    - b. Zero

Assignment Sheet 10

1. a. 20v negative
    - b. 20v positive
    - c. 40v positive
    - d. 60v positive

2. a. Negative 50v
   b. Negative 30v
   c. Positive 30v
   d. Positive 70v
   e. Positive 120v

Assignment Sheet #11

1. a. Negative 10 volts
   b. Positive 10 volts
   c. Positive 20 volts
2. a. 30
   b. 1a
   c. 10v
   d. 10v
   e. 10v
3. c
4. a. 5
   b. 25
   c. 1.2a
   d. 12v
   e. 12v
   f. 6v
5.

	R_T	I_T	E_{R1}	E_{R2}	E_{R3}
Add R4	↓	↑	↑	↑	↓

6. 6 volts
7. No

SERIES-PARALLEL CIRCUITS
UNIT XII

JOB SHEET #1--MEASURE AND CALCULATE QUANTITIES IN SERIES-PARALLEL CIRCUITS

I. Tools and materials

A. DC Power Supply

B. Multimeter (or equivalent)

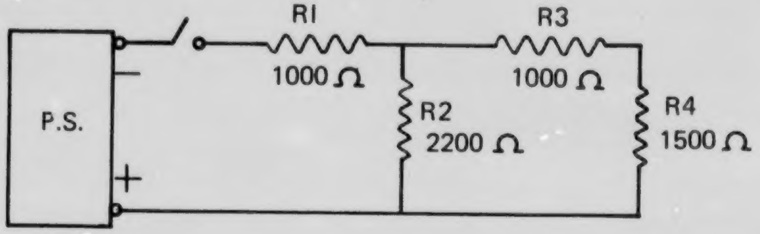
C. Two 1000, one 1500, and one 2200 ohm resistors, 1/2W or more

D. Switch-SPST

II. Procedure

A. Connect the resistors as shown in the schematic

B. Adjust the power supply to 20V and close the switch



C. Measure and record the voltage drop across each resistor (V_1, V_2,...)

D. Measure and record the current through each resistor (I_1, I_2,...)

E. Compute the power used by each resistor using the values measured in Steps C and D ($P_1 = V_1 I_1$, etc.)

F. Measure and record E_A and I_T

G. Compute R_T using the measurements of Step F

H. Compute R1, R2, R3, and R4 using the voltage drops and currents measured in Steps C and D

I. Compute R_T using the resistance values computed in Step H

JOB SHEET #1

J. Discuss the following:

1. Did the value of R_T computed in Step G differ from Step I?

   Explain.

2. Why does the resistance computed using the voltage drop and current differ from the color-coded value?

3. How much difference do you think you can permit between the computed and the color-coded values of a resistor? Why?

4. Does the total power (EI) equal the total power computed in Step E? Explain any differences

SERIES-PARALLEL CIRCUITS
UNIT XII

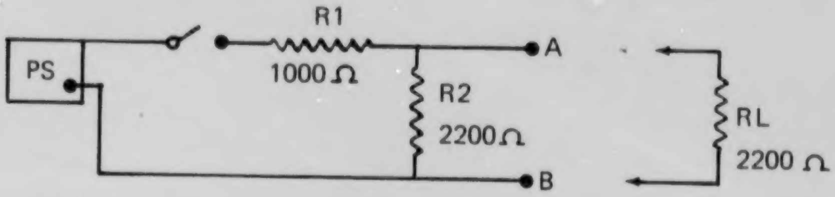
JOB SHEET #2--CONSTRUCT A VOLTAGE DIVIDER AND ANALYZE ITS FUNCTION

I. Tools and materials

- A. DC Power Supply
- B. Multimeter
- C. 1000 ohm and two 2200 ohm resistors, 1/2W or more
- D. 12-V lamp or equivalent

II. Procedure

- A. Connect the resistors in series with the power supply as shown in the following schematic.



- B. Adjust the power supply to 20V
- C. Close the switch and measure and record V_{R2} and V_{R1}
- D. Connect the load across points A and B
- E. Read and record the voltage across R1 and across R2 with the load connected
- F. Explain why V_{R1} changed when the load was connected and explain the direction of the change
- G. Explain the differences observed in V_2 with and without the load
- H. Discuss the following
  1. Do series resistors cause voltage changes when load currents change? How and in what way?
  2. When the load is connected does the power supply "see" a series circuit or a series-parallel circuit?

SERIES-PARALLEL CIRCUITS
UNIT XII

NAME______________________________

TEST

1. Match the terms on the right with their correct definitions.

______a. Simplifying a circuit by combining elements

______b. A circuit which contains some components in series and others in parallel

______c. A system of resistors connected across a voltage source to permit the tapping of voltages of different values

______d. A voltage reference point which may indicate a current return path to one side of the voltage source

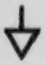
______e. A connection of one side of the voltage or current source to the metal frame of the equipment

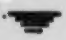
______f. A junction point in a circuit at which current divides into separate parallel branches, or reunites from parallel branches

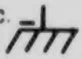
______g. Connection of one side of the voltage or current source to conductive metal which enters the earth at some point

1. Series-parallel circuit
2. Node
3. Circuit reduction
4. Voltage divider
5. Ground
6. Earth ground
7. Chassis ground

2. Match the schematic symbols for grounds with their definitions.

______a. 

______b. 

______c. 

1. Chassis ground
2. Common ground
3. Earth ground

3. State Kirchhoff's current law.

4. Arrange in proper order the steps to simplify a series-parallel circuit by placing the correct sequence number in the appropriate blanks.

______a. Combine all equivalent resistances and series resistances to determine total resistance

______b. Reduce each parallel group to an equivalent resistance, R_{eq}

______c. Trace current flow and indicate polarity

______d. Determine total current by dividing applied voltage by total resistance

______e. Identify series resistors

______f. Redraw the circuit using a single resistor to represent each equivalent resistance

______g. Identify nodes

______h. Identify series or parallel groups of resistors

5. Select true statements describing the function of ground as a voltage reference by placing an "X" in the appropriate blanks.

______a. Only earth grounds may be used in circuits

______b. Use of grounds helps simplify the schematic

______c. Ground may be the common return path for current

______d. A ground prohibits the generation of both positive and negative voltages

______e. Chassis ground permits use of the chassis for the voltage reference point for all voltage measurements

6. Select true statements which describe the functions of a voltage divider by placing an "X" in the appropriate blanks.

______a. Tapped voltages must be either all positive or all negative

______b. If the load draws appreciable current, the voltage division differs from the no-load condition

______c. Chassis ground is often used as the zero reference point

______d. A load is connected in series with the resistor from which the voltage is tapped

______e. A voltage divider allows tapping off of different voltages for various applications

7. Demonstrate the ability to:

   a. Measure and calculate quantities in series-parallel circuits

   b. Construct a voltage divider and analyze its function

   (NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

SERIES-PARALLEL CIRCUITS
UNIT XII

ANSWERS TO TEST

1. a. 3
   b. 1
   c. 4
   d. 5
   e. 7
   f. 2
   g. 6

2. a. 2
   b. 3
   c. 1

3. The sum of all the currents flowing into a point or junction in a circuit is equal to the sum of all the currents flowing away from that point or junction

4. a. 7
   b. 5
   c. 1
   d. 8
   e. 3
   f. 6
   g. 2
   h. 4

5. b, c, e

6. b, c, e

7. Performance skills evaluated to the satisfaction of the instructor

MAGNETISM
UNIT XIII

UNIT OBJECTIVE

After completion of this unit, the student should be able to select true statements about magnetic lines of force, magnetic fields, and magnetic flux, and discuss the method and effect of induction. The student should also be able to show the existence of magnetic lines around a magnet, demonstrate that magnetic poles can attract and repel, and construct an electromagnet and check its operation. This knowledge will be evidenced by correctly performing the procedures outlined on the job sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms associated with magnetism with their correct definitions.
2. Name two types of natural magnets and two types of artificial magnets.
3. Name two ways of producing artificial magnets.
4. Distinguish between high, medium, low, and nonpermeable magnetic materials.
5. Select true statements concerning magnetic lines of force, magnetic fields, magnetic flux, and flux density.
6. Discuss the use of the left-hand rules for conductors and coils using an illustration.
7. Discuss the method and effect of induction.
8. List practical applications of induction in the electronics field.
9. Demonstrate the ability to:
    a. Show the existence of magnetic lines of force around a magnet.
    b. Demonstrate that magnetic poles can attract and repel.
    c. Construct a simple electromagnet and check its operation.

MAGNETISM
UNIT XIII

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information and job sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information sheets.

VI. Demonstrate and discuss the procedures outlined in the job sheets.

VII. Use overhead projector, sheet of transparency, magnets, and iron filings to demonstrate magnetic lines of force.

VIII. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

  A. Objective sheet

  B. Information sheet

  C. Transparency masters

    1. TM 1--Magnetic Poles
    2. TM 2--Types of Magnets
    3. TM 3--Producing Artificial Magnets
    4. TM 4--Magnetic Lines of Force
    5. TM 5--Magnetic Flux and Flux Density
    6. TM 6--Induction

  E. Job sheets

    1. Job Sheet #1--Show the Existence of Magnetic Lines of Force Around a Magnet
    2. Job Sheet #2--Demonstrate that Magnetic Poles can Attract and Repel
    3. Job Sheet #3--Construct a Simple Electromagnet and Check Its Operation

F. Test

G. Answers to test

II. References:

A. Grob, Bernard. *Basic Electronics*. 5th ed., New Yo[illegible] McGraw-Hill Book Co., 1977.

B. Marcus, Abraham. *Basic Electronics*. Englewood Cliffs, NJ: Prentice-Hall, Inc., 1974.

C. Terman, F. E. *Radio Engineer's Handbook*. New York: McGraw-Hill Book Co., 1952.

MAGNETISM
UNIT XIII

INFORMATION SHEET

I. Terms and definitions

A. Magnetism--A property of certain materials (e.g., iron, nickel, and cobalt) which exerts a mechanical force on other magnetic materials, and which can cause induced voltages in conductors when relative movement is present

B. Magnet--An object which will attract iron, nickel, or cobalt and which will produce an external magnetic field

C. Natural magnet--Any material found in the earth which exhibits the properties of magnetism

Example: The lodestone, which contains magnetite, a form of iron, and which has been magnetized by the earth's magnetic field

D. Artificial magnet--A device which has been made magnetic by induction

E. Induction--The process of magnetizing an object by bringing it into the magnetic field of an electromagnet or permanent magnet

F. Magnetic lines of force--An imaginary line in a magnetic field that coincides in direction with the field intensity at each point and which has a direction from the North to the South pole

G. Magnetic field--The area around a magnet through which the lines of force flow

H. Permanent magnet--A magnetic device which retains its magnetism after it is removed from a magnetic field

I. Electromagnet--A core of soft iron that is temporarily magnetized by sending current through a coil of wire wound around the core

J. Permeability--A measure of the effectiveness of a material as a path for magnetic lines of force as compared with the effectiveness of air

(NOTE: Some materials such as iron have high permeability, others such as aluminum have medium permeability, and others such as silver and gold have low permeability.)

K. Magnetic poles--The portion of a magnet where the magnetic lines appear to concentrate (Transparency 1)

(NOTE: By convention the north-seeking pole is marked with N, or plus, or is colored red.)

INFORMATION SHEET

L. Ferromagnetic--Magnetic materials with high values of permeability which range from 50 to 5000

(NOTE: Steel, cobalt, nickel, and alnico are ferromagnetic materials.)

M. Diamagnetic--Magnetic materials with a permeability of less than one

(NOTE: Diamagnetic materials include bismuth, antimony, copper, and zinc.)

II. Types of magnets (Transparencies 2 and 3)

A. Natural magnets

1. The earth
2. Lodestone

B. Artificial magnets

1. Electromagnets
2. Permanent magnets

III. Ways of producing artificial magnets

A. Electrical coil method

B. Stroking method

IV. Permeability of magnetic materials

A. High permeability

1. Iron
2. Steel
3. Nickel
4. Cobalt
5. Commercially made alloys of iron, nickel, cobalt and other elements

a. Silicon steel

(NOTE: Silicon steel is used in transformers.)

b. Alnico

(NOTE: Alnico is used in audio speakers.)

INFORMATION SHEET

B. Medium permeability
    1. Aluminum
    2. Platinum
    3. Manganese
    4. Chromium

C. Low permeability
    1. Bismuth
    2. Antimony
    3. Copper
    4. Zinc
    5. Rare metals (mercury, gold, silver)

D. Nonmagnetic materials
    1. Glass
    2. Paper
    3. Rubber
    4. Wood
    5. Air

V. Magnetic properties

A. Magnetic lines of force (Transparency 4)
    1. Continuous and form complete loops
    2. Never cross each other
    3. Cause like poles (north-north, south-south) to repel each other
    4. Cause unlike poles (north-south, south-north) to attract each other
    5. Parallel lines going in the same direction repel each other
    6. Attract other lines going in the opposite direction

INFORMATION SHEET

7. Exert tension along their lengths, tending to shorten themselves

   (NOTE: If the two poles of a magnet could move, the lines of force would eventually pull the two poles together.)

8. Pass through all materials, both magnetic and nonmagnetic

9. Always enter or leave magnetic material at right angles to the surface

10. Tend to flow in paths of least opposition

B. Magnetic field

   1. Area around magnet through which force lines flow

   2. Direction of flow is always from north pole to south pole

C. Magnetic flux (Transparency 5)

   1. Sum total of magnetic field force lines flowing from north pole to south pole

   2. Symbol for magnetic flux--Greek letter phi (Φ)

   3. Unit of flux--Maxwell; one maxwell (Mx) equals one line of force

      Example: If a magnetic field contains 6 lines of force, the flux of the magnet is 6 maxwells, or $\Phi = 6\text{Mx}$

   4. Flux density--Number of force lines per given area

      a. Symbol--B

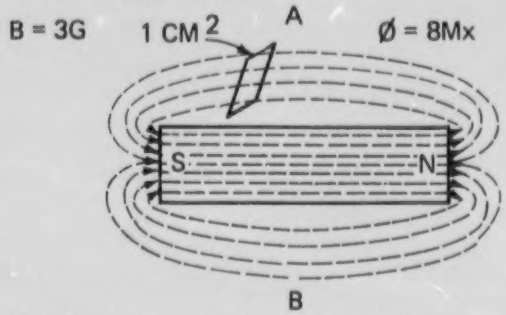
      b. Unit of flux density--Gauss (G); one gauss (G) equals one force line per square centimeter

      c. In the magnetic field shown in Figure 1, total magnetic flux (from point A to point B) is 8 lines of force, or 8 maxwells, expressed as $\Phi = 8\text{Mx}$

INFORMATION SHEET

d. The flux density (B) in one square centimeter (1 cm^2) equals 3 gauss, expressed as B = 3G

FIGURE 1



(NOTE: A typical one pound magnet might have a magnetic flux of 5000 maxwells, and a flux density of 1000 gauss.)

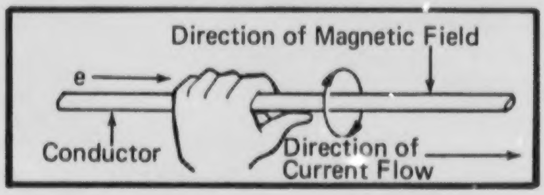
VI. The use of the left-hand rule for conductors and coils

A. Left-hand rule for conductors (Figure 1)

1. Grasp conductor with left hand as shown, making sure thumb is pointing in direction of electron flow in the conductor

2. Direction of magnetic field flow is in the direction of the four fingers, from large knuckles toward fingertips

FIGURE 2

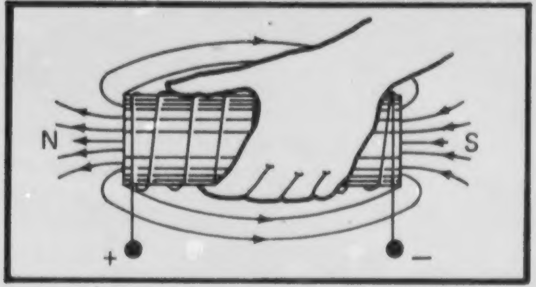


B. Left-hand rule for coils

1. Grasp the coil with left hand as shown below so that the four fingers (from knuckles to fingertips) point in direction of electron flow through the coiled conductor

2. The thumb now points toward the north pole of the electromagnet

FIGURE 3



INFORMATION SHEET

VII. Induction (Transparency 6)

   A. Method

      1. Place iron bar in vicinity of permanent magnet

      2. Do not allow iron bar to touch magnet

   B. Effect

      1. Magnetic field lines of force flow through the iron bar

      2. The iron bar becomes electromagnetized

      3. Pole polarity is reversed

         a. End of bar near north pole of magnet becomes south pole of bar

         b. End of bar near south pole of magnet becomes north pole of bar

      4. The permanent magnet attracts the iron bar

      (NOTE: This constitutes more action.)

VIII. Practical applications of induction in the electronics field

   A. Radio and television transmission and reception

   B. Transformers

   C. Relays and solenoids

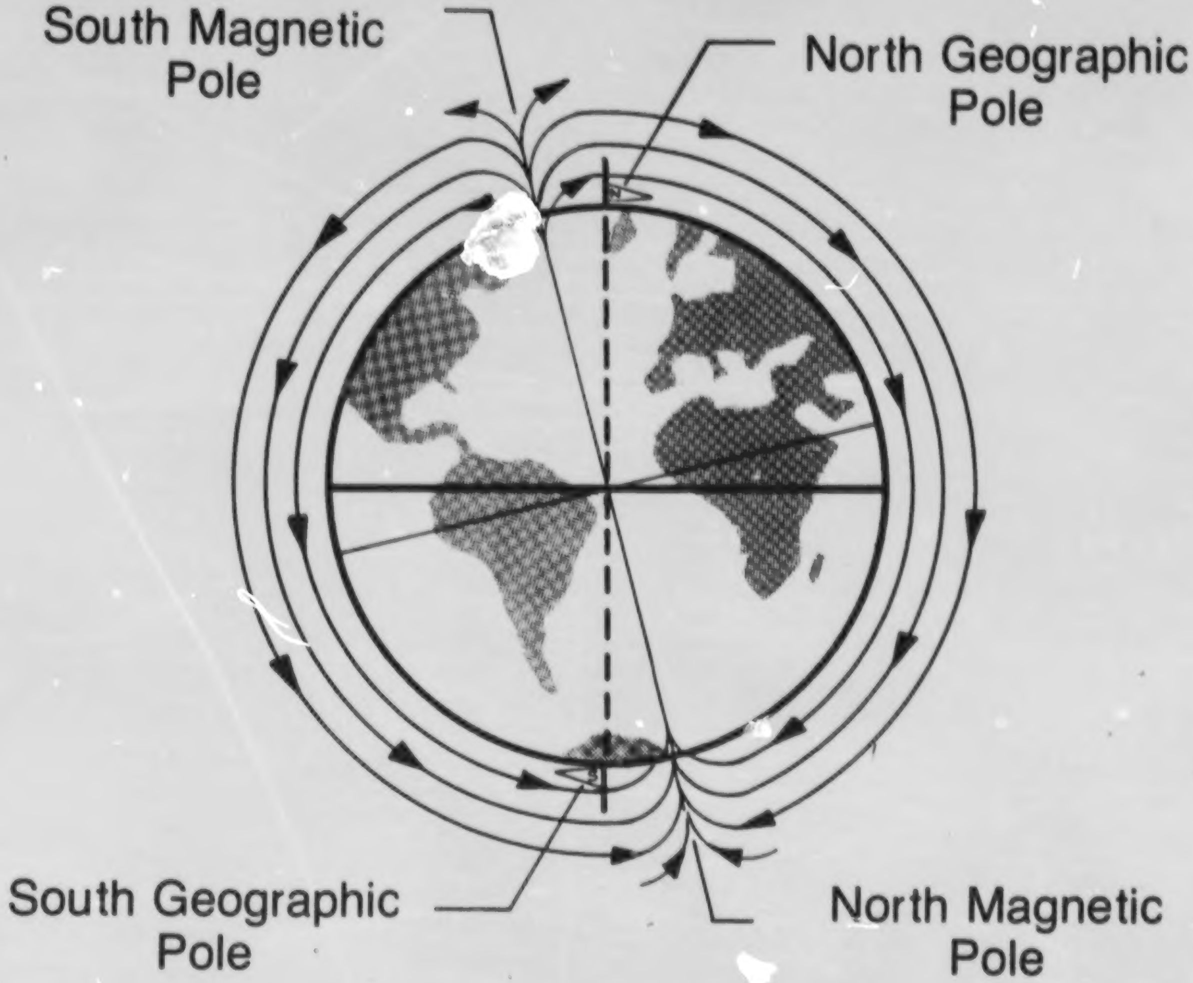
   D. Coils, chokes, and inductors

   E. Audio speakers

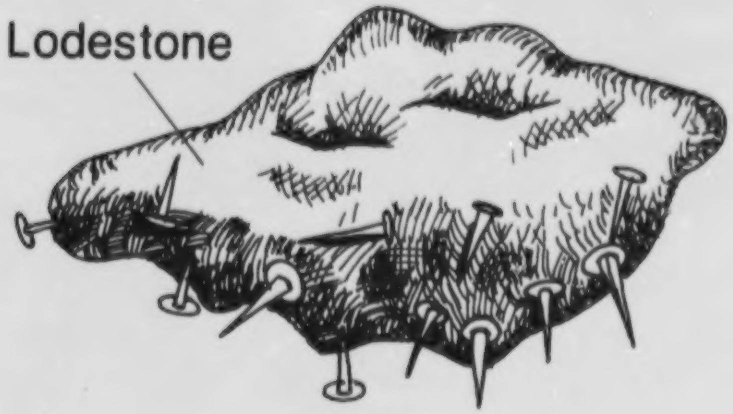
   F. Motors and generators

   G. Magnetic memory

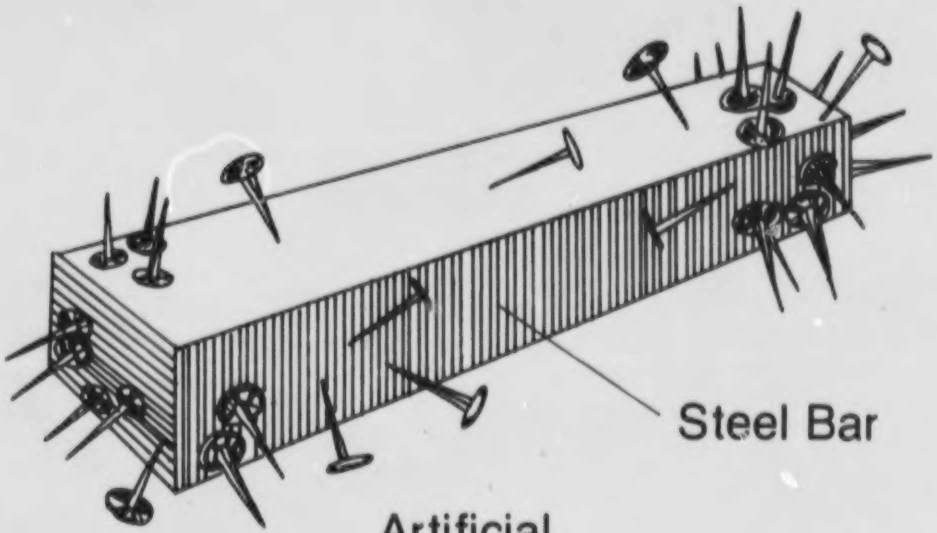
Magnetic Poles


South Magnetic Pole
North Geographic Pole
South Geographic Pole
North Magnetic Pole

Types of Magnets

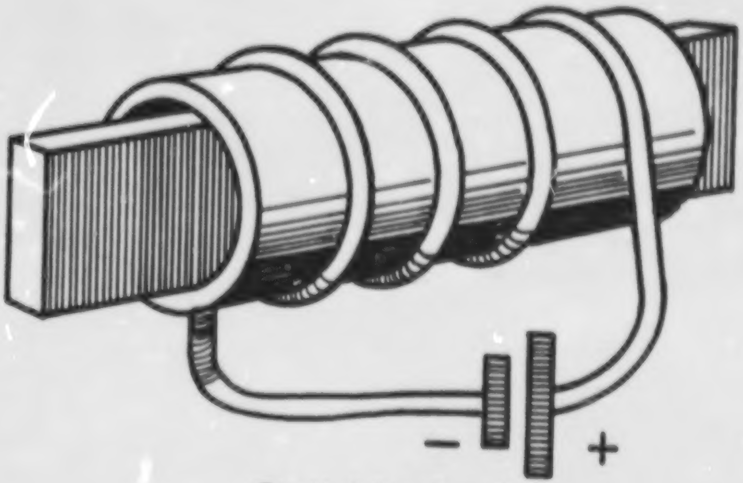


Natural

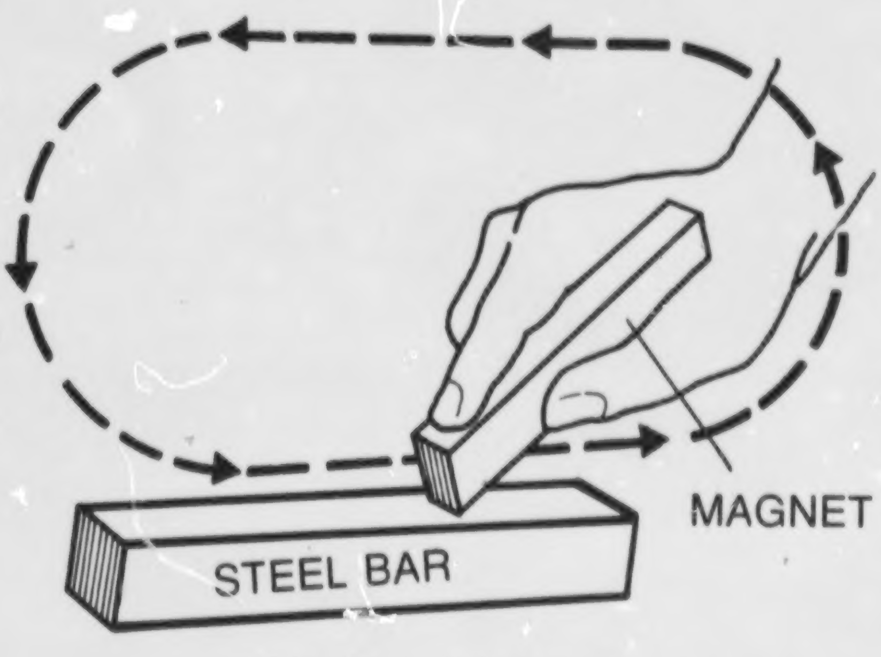


Artificial

Producing Artificial Magnets

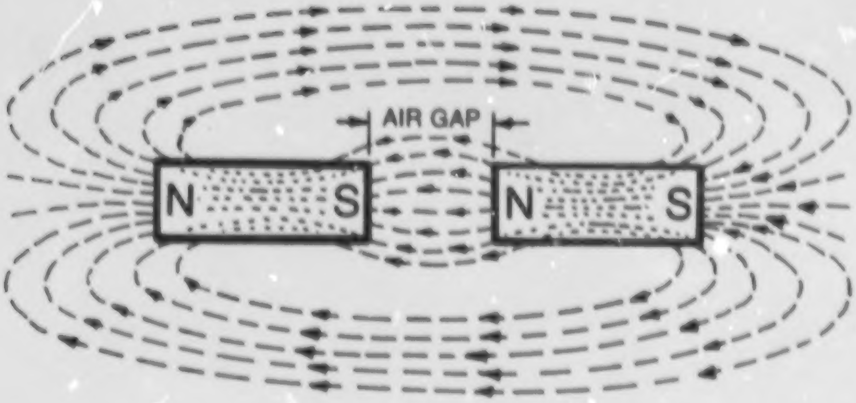


Coil Method

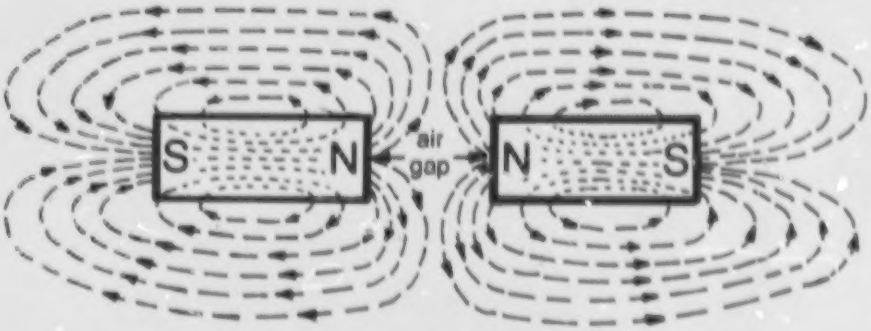

MAGNET
STEEL BAR

Stroking Method

Magnetic Lines of Force


AIR GAP
N
S
N
S

Unlike Poles Attract


S
N
air
gap
N
S

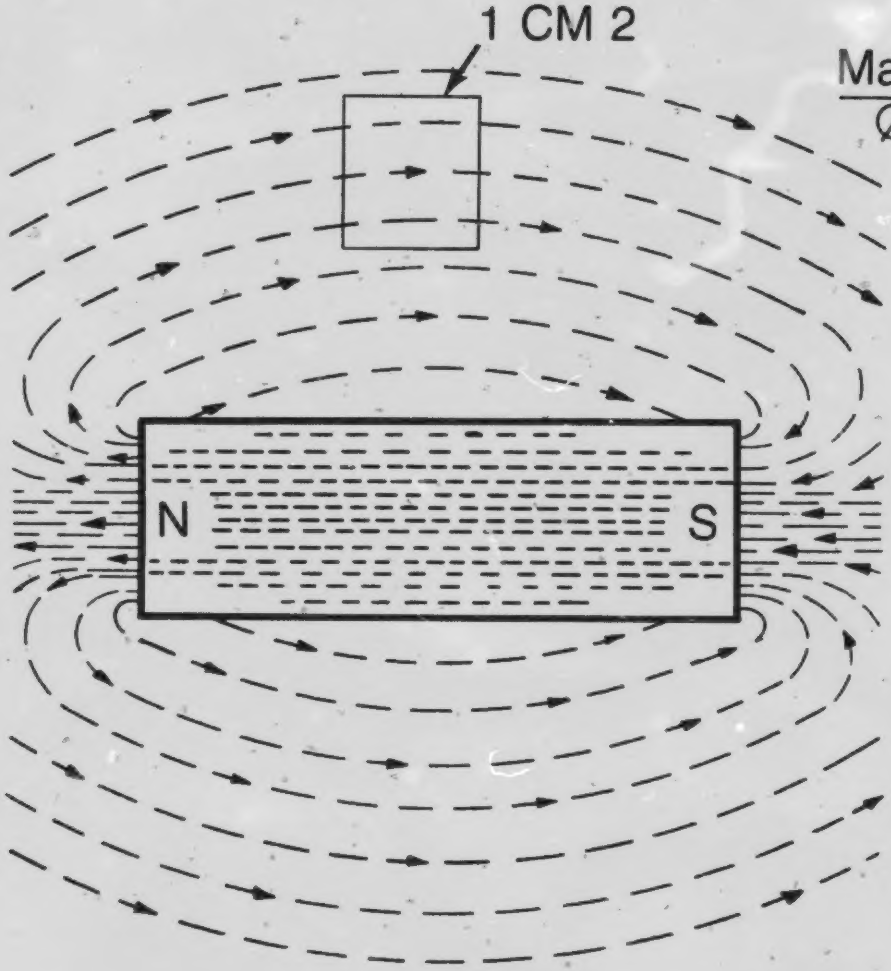
Lines of Force

Like Poles Repel

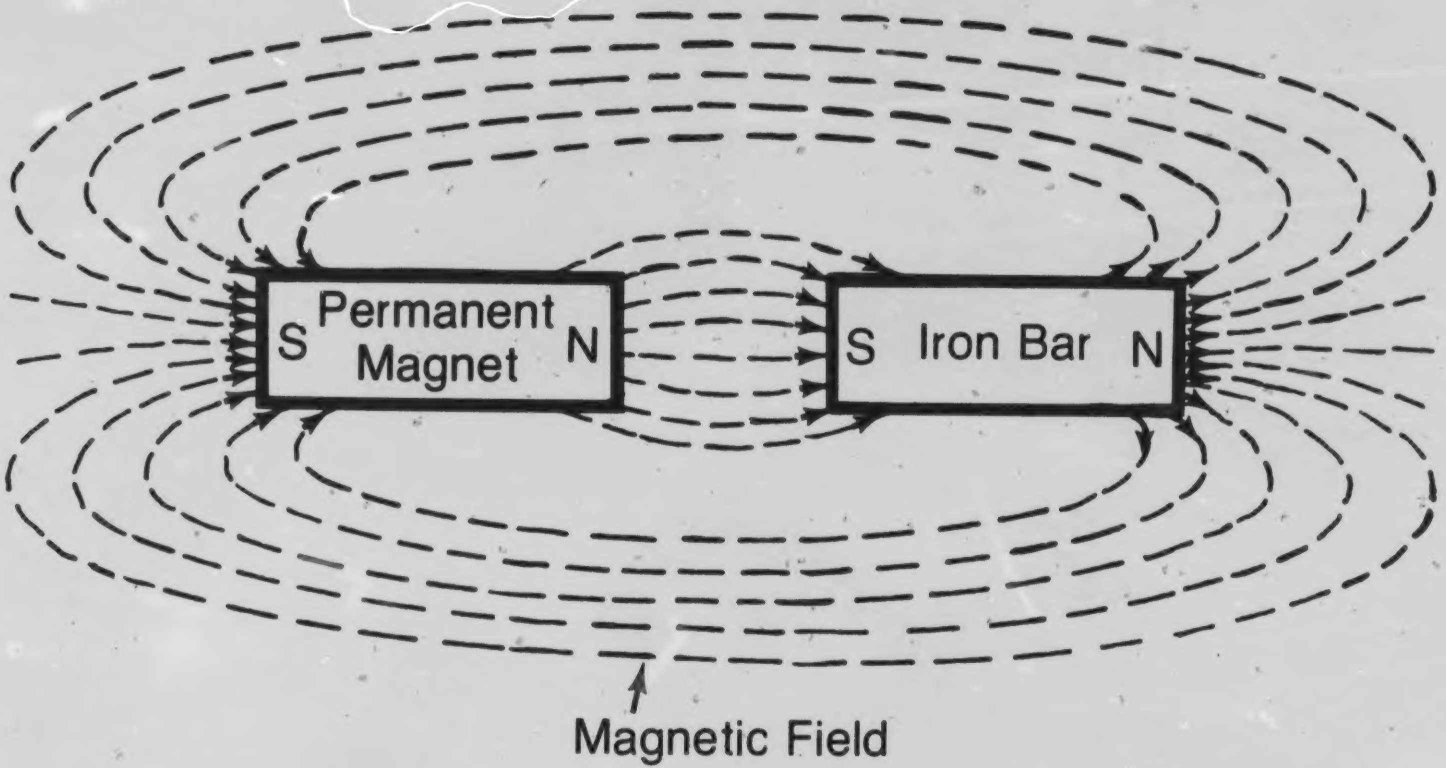
Magnetic Flux and Flux Density

Flux Density
B = 3 G

Magnetic Flux
Ø = 14 Mx



Induction


S
Permanent Magnet
N
S
Iron Bar
N
Magnetic Field

Note Opposite North-South Poles

MAGNETISM
UNIT XIII

JOB SHEET #1--SHOW THE EXISTENCE OF MAGNETIC LINES OF FORCE AROUND A MAGNET

I. Equipment and materials

A. One magnet

B. Compass

C. Flat piece of glass or clear lucite (approximately 8" x 10")

D. Shaker of iron filings

II. Procedure

A. With compass at least 5 yards away from your magnet, see that the needle points to earth's "north"

B. Bring the compass to within 4 inches of one pole of your magnet and observe the change in the compass needle indication

C. Bring the compass to within 4 inches of the magnet's other pole and observe the change in the compass needle indication

D. Place the magnet under the center of the flat piece of glass

E. Using the sketch below, move the compass into the positions indicated by number

F. Record the needle indication at each of the positions

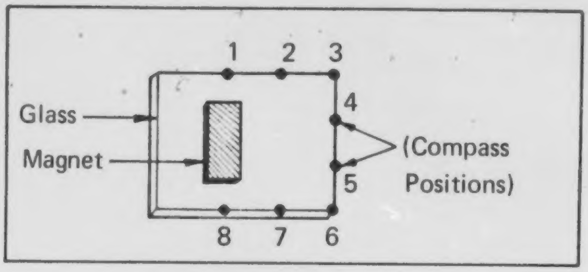


FIGURE 1

G. With the magnet still under the center of the flat piece of glass, sprinkle iron filings on top of the glass

H. Observe the lines of flux indicated by the iron filings

JOB SHEET #1

I. Make a sketch of the pattern formed by the filings

(NOTE: The following questions may be used for discussion:

1. Does the compass indicate that there is a force surrounding your magnet? Do the compass indications show the direction of the flux lines? Explain why your compass indicates this flow.

2. Do the iron filings concentrate at the poles? Why are the lines of flux spread out when not in the vicinity of the poles? Give two reasons. Do the lines cross each other? Give at least three other characteristics of magnetic fields that are illustrated by the position of the iron filings.)

MAGNETISM
UNIT XIII

JOB SHEET #2--DEMONSTRATE THAT MAGNETIC POLES CAN ATTRACT AND REPEL

I. Equipment and materials

A. Two magnets

B. Piece of flat glass (approximately 8" x 10")

(NOTE: Clear lucite can be used.)

C. Small piece of iron

D. Small piece of brass

E. Shaker of iron filings

II. Procedure

A. Place one magnet on a smooth surface

B. Bring the north pole of the other magnet close to the north pole of the first one

C. Observe the action of the magnets

D. Repeat steps A, B, and C but bring the north pole of one magnet close to the south pole of the other

E. Observe the action of the magnets

F. Place the magnets under the glass with *unlike* poles opposite, but not touching, each other

G. Sprinkle iron filings over the glass and sketch the resulting pattern

H. Lift the glass and replace the iron filings into the shaker

I. Place the magnets under the glass with *like* poles opposite, but not touching, each other

J. Sprinkle iron filings over the glass and sketch the resulting pattern

K. Replace the filings into the shaker

L. Place one magnet under the glass

JOB SHEET #2

M. On one end of the glass place the small piece of iron close to the pole of the magnet but not directly over the pole

N. On the other end in a similar position, place the small piece of brass close to the other pole of the magnet

O. Sprinkle iron filings on the glass, brass, and iron pieces

P. Sketch the resulting pattern

(NOTE: The following questions may be used for discussion:

1. Explain the reactions of the magnets in steps A, B, C, and D.
2. Explain how the sketches of like poles and of unlike poles show that there are forces of repulsion and attraction.
3. What happened to the lines of force as they passed through the small piece of iron? What happened as they passed through the small piece of brass? Do the lines of force also pass through the glass? Explain your sketch made in step P.)

MAGNETISM
UNIT XIII

JOB SHEET #3--CONSTRUCT A SIMPLE ELECTROMAGNET AND CHECK ITS OPERATION

I. Equipment and materials needed

A. 1 1/2-volt battery

(CAUTION: Use no more than 1.5 volts!)

B. 4 feet hook-up wire (insulated)

C. 1/4" iron bolt, 3" long

D. Compass

E. Paper clips

II. Procedure

A. Start at one end of the hook-up wire and wrap all of the wire around the bolt, leaving approximately 8 inches on both ends so you can hook your coil to the battery

B. Before connecting the coil to the battery, check to see that the iron bolt is not a magnet

(NOTE: Do this by bringing the compass within 4 inches of each end of the bolt and observe little or no change in the compass needle.)

C. Connect the coil to the battery

D. Bring the compass within 4 inches of the bolt ends and observe the needle indications for north and south poles

E. See if the bolt will pick up the paper clips

(NOTE: Try both ends of the bolt.)

F. Disconnect the coil from the battery

G. Carefully remove the bolt trying to keep the coil in its same shape

H. Reconnect the coil to the battery

I. Check for polarity and magnetism with your compass by bringing it close to the coil ends

J. See if the coil will attract a paper clip

(NOTE: Try both ends of the coil.)

JOB SHEET #3

K. Disconnect the battery

(NOTE: The following questions may be used for discussion:

1. Is the left-hand rule for coils confirmed by your observations in step C? Explain how the compass confirms the left-hand rule.
2. Explain why both ends of the electromagnet with the bolt in position will pick up the paper clips.
3. Why was the coil weaker without the bolt? Explain why the polarity observed with the compass was the same with or without the bolt.)

MAGNETISM
UNIT XIII

NAME ______________________________

TEST

1. Match the terms on the right with the correct definitions.

   _____a. A measure of the effectiveness of a material as a path for magnetic lines of force as compared with the effectiveness of air

   _____b. The portion of a magnet where the magnetic lines appear to concentrate

   _____c. The area around a magnet through which the lines of force flow

   _____d. Any material found in the earth which exhibits the properties of magnetism

   _____e. A property of certain materials which exerts a mechanical force on other magnetic materials, and which can cause induced voltages in conductors when relative movement is present

   _____f. A device which has been made magnetic by induction

   _____g. A core of soft iron that is temporarily magnetized by sending current through a coil of wire wound around the core

   _____h. An object which will attract iron, nickel, or cobalt and which will produce an external magnetic field

   _____i. The process of magnetizing an object by bringing it into the magnetic field of an electromagnet or permanent magnet

   _____j. A magnetic device which retains its magnetism after it is removed from a magnetic field

   _____k. An imaginary line in a magnetic field that coincides in direction with the field intensity at each point and which has a direction from the North to the South pole

   1. Magnetism
   2. Magnet
   3. Magnetic poles
   4. Magnetic lines of force
   5. Ferromagnetic
   6. Induction
   7. Permeability
   8. Diamagnetic
   9. Artificial magnet
   10. Permanent magnet
   11. Electromagnet
   12. Magnetic field
   13. Natural magnet

_____l. Magnetic materials with high values of permeability which range from 50 to 5000

_____m. Magnetic materials with a permeability of less than one

2. Name two types of natural magnets and two types of artificial magnets.

   a. Natural magnets

      1)

      2)

   b. Artificial magnets

      1)

      2)

3. Name two ways of producing artificial magnets.

   a.

   b.

4. Distinguish between high, medium, low, and nonpermeable magnetic materials by placing an "H" next to the high, an "M" next to the medium, an "L" next to the low, and an "N" next to the nonmagnetic materials.

_____a. Bismuth

_____b. Aluminum

_____c. Silicon steel

_____d. Rubber

_____e. Air

_____f. Iron

_____g. Wood

_____h. Cobalt

_____i. Rare metals

_____j. Platinum

_____k. Glass

______l. Nickel

______m. Antimony

______n. Copper

______o. Manganese

______p. Paper

______q. Steel

______r. Zinc

______s. Chromium

______t. Alnico

5. Select true statements concerning magnetic lines of force, magnetic fields, magnetic flux, and flux density by placing an "X" in the appropriate blanks.

______a. The magnetic lines of force are continuous and form complete loops

______b. The magnetic lines of force never cross each other

______c. The direction of flow is from south pole to north pole

______d. Parallel lines going in opposite directions repel each other

______e. The magnetic lines of force cause unlike poles to attract each other

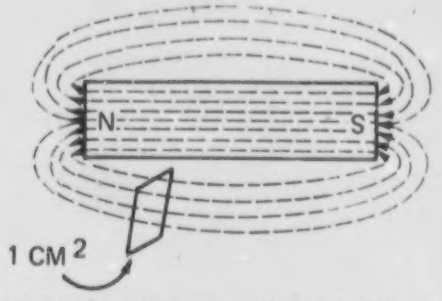
______f. Magnetic lines of force exert tension along their lengths, tending to lengthen themselves

______g. The lines of force tend to flow in the path of highest opposition

______h. The lines of force pass through all materials, magnetic and nonmagnetic

______i. The magnetic flux of the magnet shown in Figure 1 is 4 maxwells

FIGURE 1

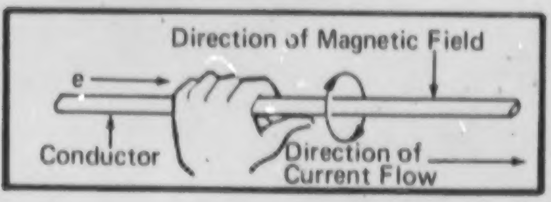


______j. Φ = 8Mx is correct for the magnet shown in Figure 1

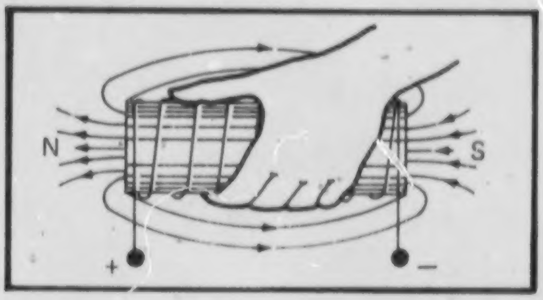
______k. The flux density for the magnet shown in Figure 1 is: B = 4G

6. Discuss the use of the left-hand rule for conductors and coils using the following illustrations.

   a. Left-hand rule for conductors


Direction of Magnetic Field
e
Conductor
Direction of Current Flow

   b. Left-hand rule for coils



7. Discuss the method and effect of induction.

   a. Method

   b. Effect

8. List four practical applications of induction in the electronics field.

   a.

   b.

   c.

   d.

9. Demonstrate the ability to:

   a. Show the existence of magnetic lines of force around a magnet.

   b. Demonstrate that magnetic poles can attract and repel.

   c. Construct a simple electromagnet and check its operation.

(NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

MAGNETISM
UNIT XIII

ANSWERS TO TEST

1. a. 7
   b. 3
   c. 12
   d. 13
   e. 1
   f. 9
   g. 11
   h. 2
   i. 6
   j. 10
   k. 4
   l. 5
   m. 8

2. a. 1) The earth
      2) Lodestone
   b. 1) Electromagnets
      2) Permanent magnets

3. a. Electrical coil method
   b. Stroking method

4. a. L
   b. M
   c. H
   d. N
   e. N
   f. H
   g. N
   h. H
   i. L
   j. M
   k. N
   l. H
   m. L
   n. L
   o. M
   p. N
   q. H
   r. L
   s. M
   t. H

5. a, b, e, h, j

6. Discussion should include:

   a. Left-hand rule for conductors

      1) Grasp conductor with left hand as shown, making sure thumb is pointing in direction of electron flow in the conductor

      2) Direction of magnetic field flow is in the direction of the four fingers, from large knuckles toward fingertips

   b. Left-hand rule for coils

      1) Grasp the coil with left hand as shown so that the four fingers point in direction of electron flow through the coiled conductor

      2) The thumb now points toward the north pole of the electromagnet

7. Discussion should include:

   a. Method
      1) Place iron bar in vicinity of permanent magnet
      2) Do not allow iron bar to touch magnet

- b. Effect
  - 1) Magnetic field lines of force flow through the iron bar
  - 2) The iron bar becomes electromagnetized
  - 3) Pole polarity is reversed
    - a) End of bar near north pole of magnet becomes south pole of bar
    - b) End of bar near south pole of magnet becomes north pole of bar
  - 4) The permanent magnet attracts the iron bar

8. Any four of the following:

   - a. Radio and television transmission and reception
   - b. Transformers
   - c. Relays and solenoids
   - d. Coils, chokes, and inductors
   - e. Audio speakers
   - f. Motors and generators
   - g. Magnetic memory

9. Performance skills evaluated to the satisfaction of the instructor.

MOTORS
UNIT XIV

UNIT OBJECTIVE

After completion of this unit, the student should be able to discuss the production of motor torque and factors which determine motor efficiency and calculate motor power and efficiency. The student should also be able to produce motor action from a current-carrying conductor in a magnetic field and calculate horsepower of a small motor. This knowledge will be evidenced by correctly performing the procedures outlined on the assignment and job sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms associated with motors with the correct definitions.
2. Discuss the direction of magnetic field flow surrounding a conductor.
3. Select true statements concerning the requirements for motor action.
4. Discuss the production of motor torque.
5. List methods of increasing motor torque.
6. Discuss factors which determine motor efficiency.
7. State the formula for determining motor efficiency.
8. Identify basic parts of a DC motor.
9. Determine direction of induced magnetic fields, induced currents, and motor action caused by induction.
10. Calculate motor power and efficiency.
11. Match motor torque and electron flow with directional arrows.
12. Demonstrate the ability to:
    a. Produce motor action from a current-carrying conductor in a magnetic field.
    b. Calculate horsepower of a small motor.

MOTORS
UNIT XIV

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information, assignment, and job sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information and assignment sheets.

VI. Demonstrate and discuss the procedures outline in job sheets.

VII. Demonstrate use of prony brake and/or dynamometer in measuring output of horsepower motors.

VIII. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

- A. Objective sheet
- B. Information sheet
- C. Transparency masters
  - 1. TM 1--Magnetic Field Around a Current-Carrying Conductor
  - 2. TM 2--Motor Action
  - 3. TM 3--Producing Motor Torque
  - 4. TM 4--Methods of Increasing Motor Torque
  - 5. TM 5--Prony Brake
  - 6. TM 6--Basic DC Motor
- D. Assignment sheets
  - 1. Assignment Sheet #1--Determine the Direction of Induced Magnetic Fields, Induced Currents, and Motor Action Caused by Induction
  - 2. Assignment Sheet #2--Calculate Motor Power and Efficiency
  - 3. Assignment Sheet #3--Match Motor Torque and Electron Flow with Directional Arrows

E. Answers to assignment sheets

F. Job sheets

  1. Job Sheet #1--Produce Motor Action From a Current-Carrying Conductor in a Magnetic Field

  2. Job Sheet #2--Calculate Horsepower of a Small Motor

G. Test

H. Answers to test

II. References:

A. Grob, Bernard. *Basic Electronics.* New York: McGraw-Hill Book Co.

B. Marcus, Abraham and S. C. Gendler. *Basic Electronics.* Englewood Cliffs, NJ: Prentice-Hall Inc.

C. *Motors and Generators: How They Work.* Indianapolis: H. W. Sams Co.

D. *Fundamentals of Electricity.* Fort Sill, OK: USA Field Artillery School.

E. *Basic Electricity.* Washington, DC: USN NavPers 10086A.

MOTORS
UNIT XIV

INFORMATION SHEET

I. Terms and definitions

   A. Horsepower--A system of rating motors; the rated power

   B. Motor--A device that converts electrical energy into mechanical energy

   C. Motor action--Right angle movement of a conductor in a magnetic field

   D. Foot pounds--Unit of measure of force

   E. Torque--Force in a rotational direction

   F. Prony brake--An instrument for measuring torque

   G. Armature--The rotating part of a DC motor

   H. Field--The magnetic flux in a motor

   I. Commutator--A cylinder on the armature of two or more segments connected to the coils of a motor

   J. Brushes--Conductive material providing electrical connection to the coils of a motor

   K. Stator--Stationary part of a motor housing the armature

   L. Rotor--Rotating member of an electrical machine that has a shaft

II. Direction of magnetic field flow surrounding conductor (Transparency 1)

   A. Field is clockwise when current flows toward you

   B. Field is counterclockwise when current flows away from you

III. Requirements for motor action (Transparency 2)

   (NOTE: The left hand rule applies to motor action.)

   A. Magnetic field

      1. Magnetic field lines always flow from north to south poles

      2. Magnetic field density is always determined by field strength, that is, a strong magnet has a dense field, a weak magnet a weak field

INFORMATION SHEET

B. Conductor field

  1. Conductor field distorts magnetic field

     (NOTE: It stretches like a rubber band.)

  2. Resultant magnetic field is strongest where the two combine

C. Movement

  1. Conductor moves away from the stronger magnetic field

  2. Conductor moves at right angles to magnetic field

IV. Producing motor torque (Transparency 3)

  A. Looped wire (coil) attached to shaft

  B. Magnetic field

  C. One side of loop forced upward and other side downward

     (NOTE: A current-carrying conductor in a magnetic field tends to move at right angles to that field.)

  D. Result is rotational action (torque)

V. Methods of increasing motor torque (Transparency 4)

  A. Use more than one coil

  B. Decrease air gap in coils

  C. Use magnetic material (such as iron) to support coils

  D. Increase coil current

  E. Increase magnetic field strength

  F. Increase length of coil

VI. Factors determining motor efficiency

  A. Input power (P_I)

    1. Usually measured in watts

    2. Determined by multiplying input voltage by input current (E x I)

INFORMATION SHEET

B. Output power (P_O) (Transparency 5)

1. Usually measured in horsepower (HP) by a prony brake
2. Convert horsepower to watts by multiplying by 746

   Example: P_O = (HP x 746) watts

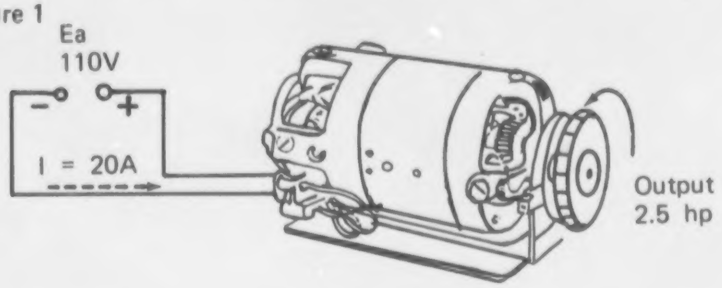
VII. Formula for determining motor efficiency--

$$\text{Efficiency (in percent)} = \frac{\text{Output Power}}{\text{Input Power}} \times 100 \text{ or } \frac{P_O}{P_I} \times 100$$

(NOTE: Be sure that output power and input power are measured in the same units.)

Example: The motor in Figure 1 has an efficiency of 85%

Figure 1



Power input = 110V x 20A = 2200 watts

$$\text{Power output} = 2.5\text{ HP} \times \frac{746\text{ watts}}{1\text{ HP}} = 1865\text{ watts}$$

$$\text{Efficiency} = \frac{P_O}{P_I} \times 100 = \frac{1865\text{ watts}}{2200\text{ watts}} \times 100 = .8477 \times 100 = 85\%$$

VIII. Basic parts of a DC motor (Transparency 6)

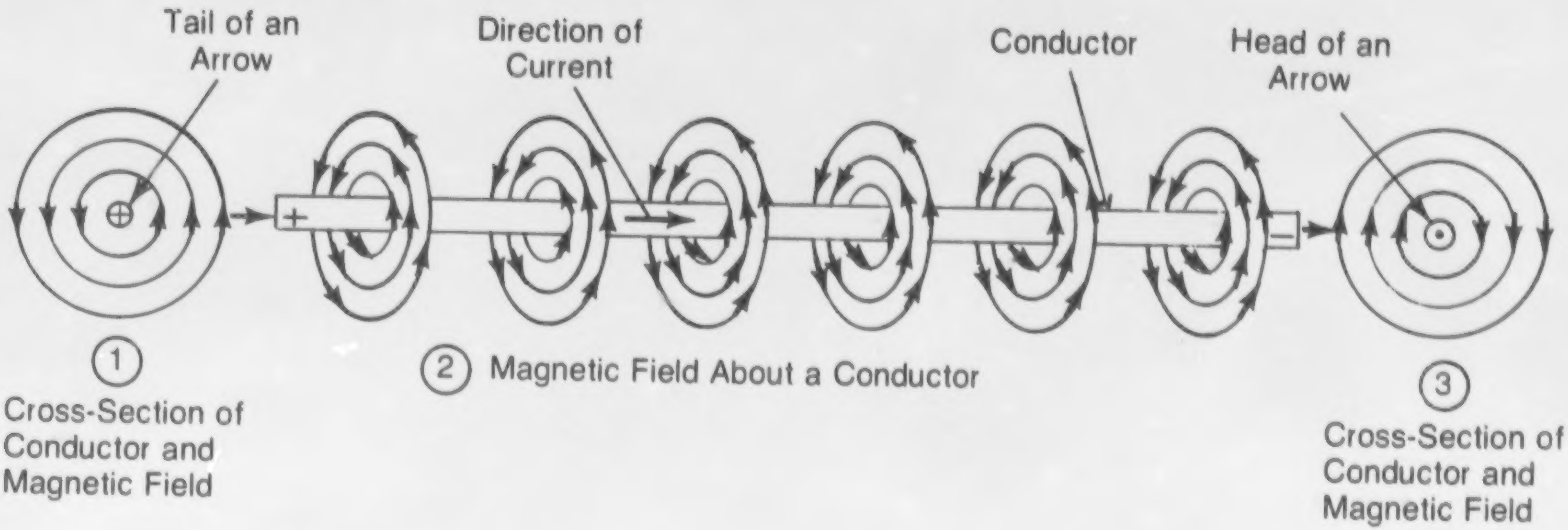
A. Field magnets

B. Armature (coil)

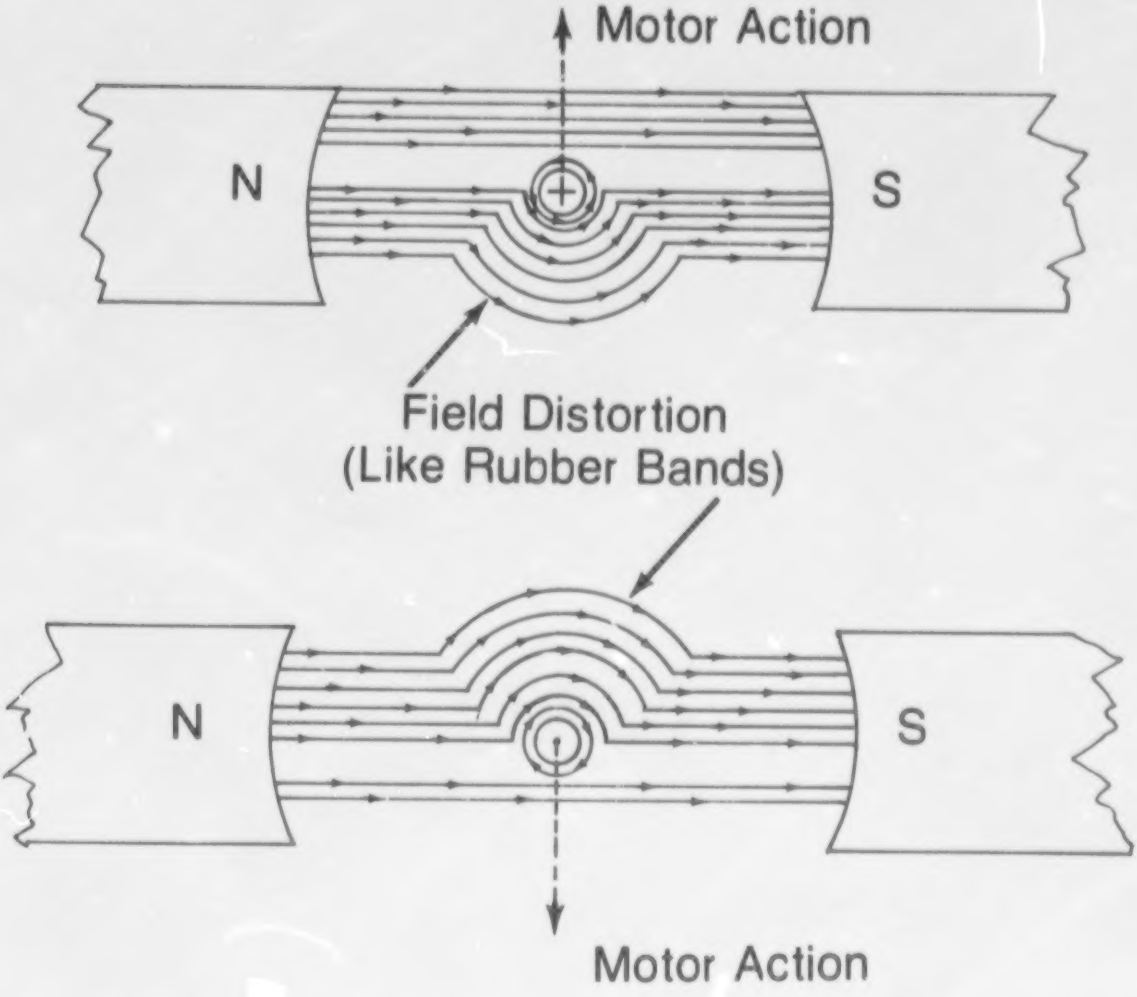
C. Commutator

D. Brushes

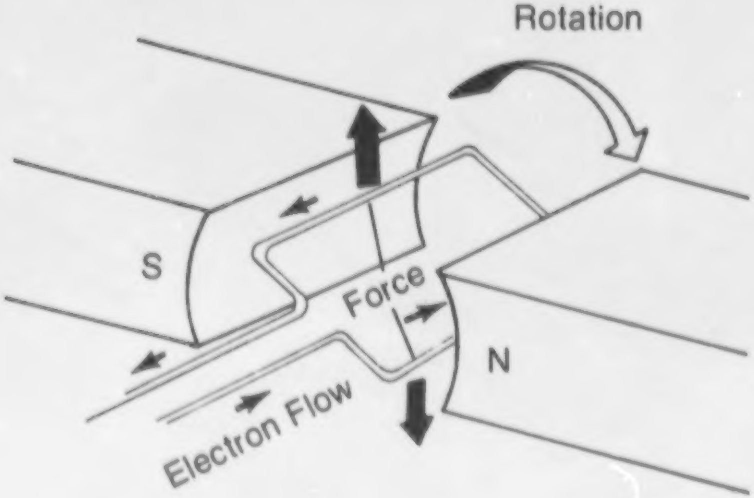
Magnetic Field Around A Current-Carrying Conductor


Tail of an Arrow
Direction of Current
Conductor
Head of an Arrow
+
−
①
Cross-Section of Conductor and Magnetic Field
② Magnetic Field About a Conductor
③
Cross-Section of Conductor and Magnetic Field

Motor Action

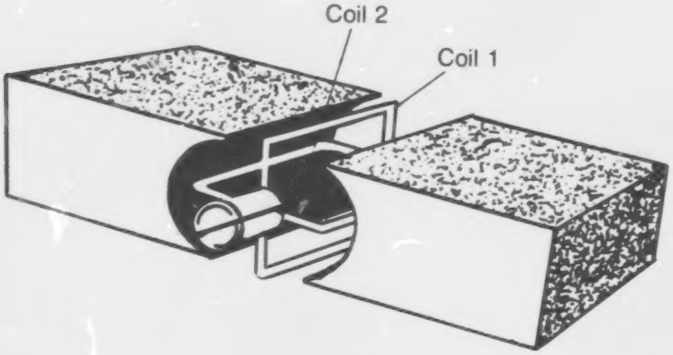

Motor Action
N
S
Field Distortion
(Like Rubber Bands)
N
S
Motor Action

Producing Motor Torque

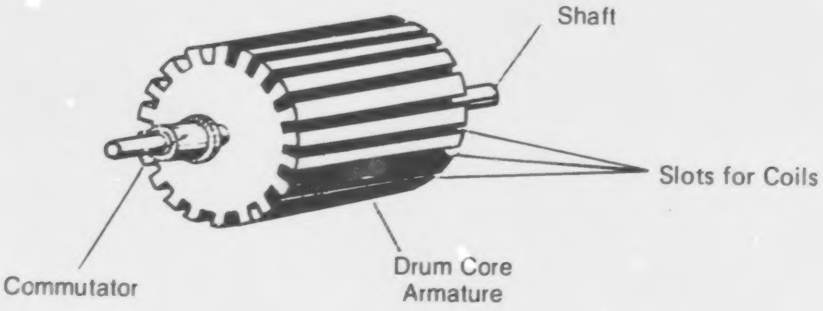

Rotation
S
Force
N
Electron Flow

Methods of Increasing Motor Torque

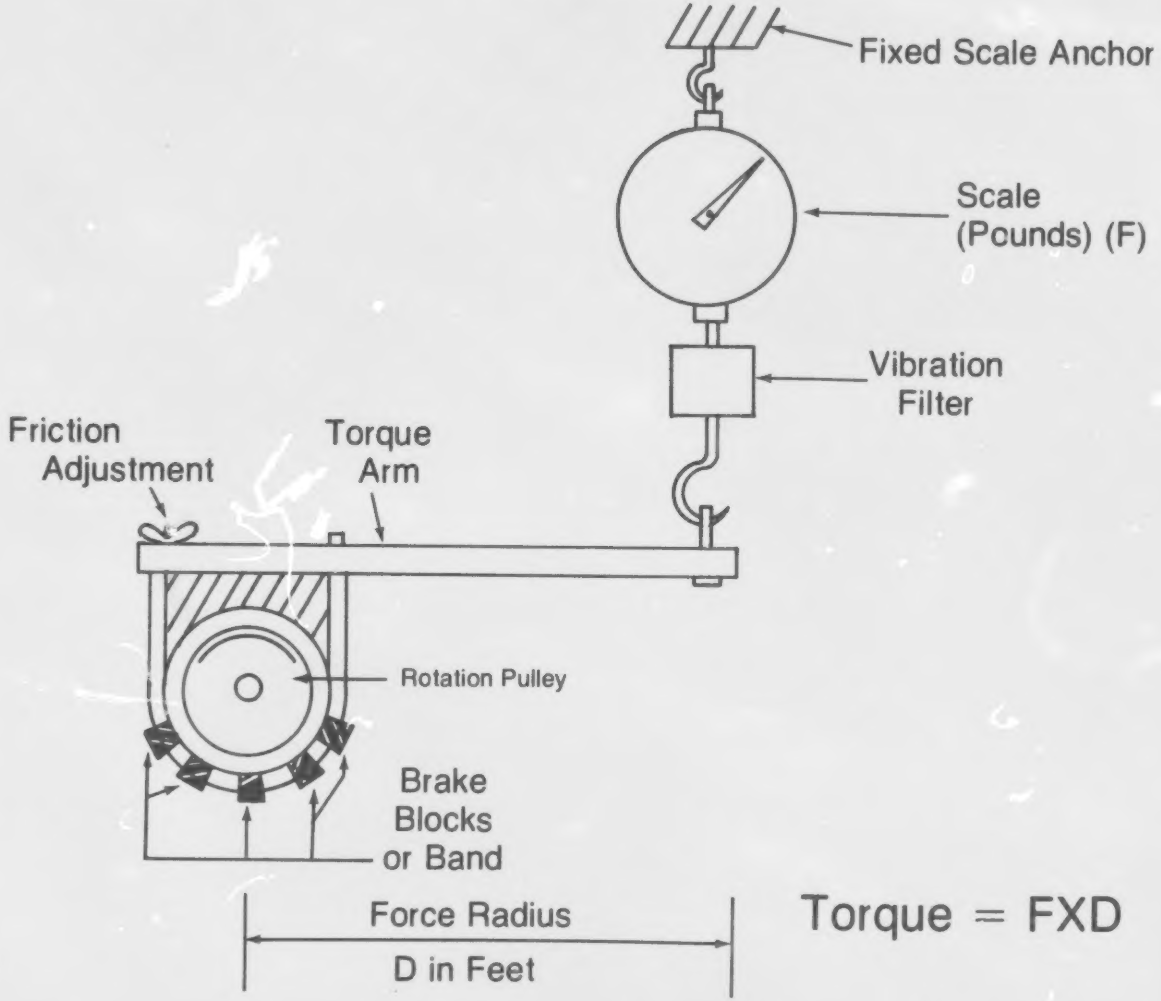
1 Use More Than One Coil


Coil 2
Coil 1

2 Eliminate Air Core Between Coils By Inserting Magnetic Material Core (Armature)

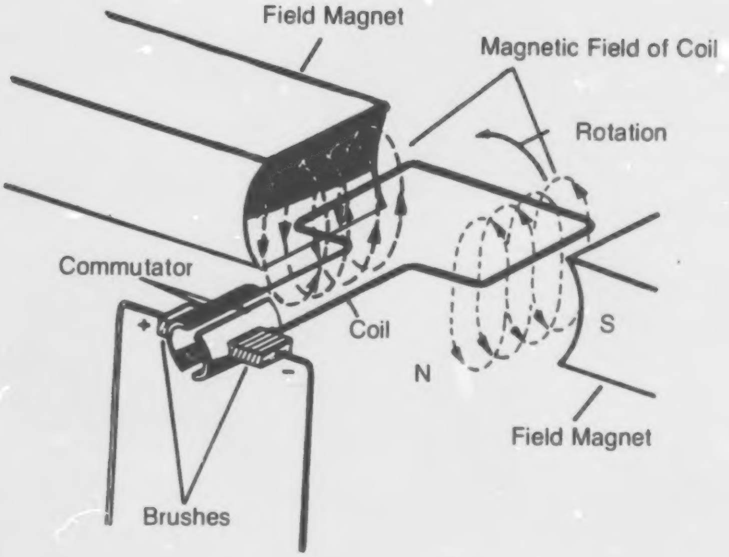

Shaft
Slots for Coils
Commutator
Drum Core Armature

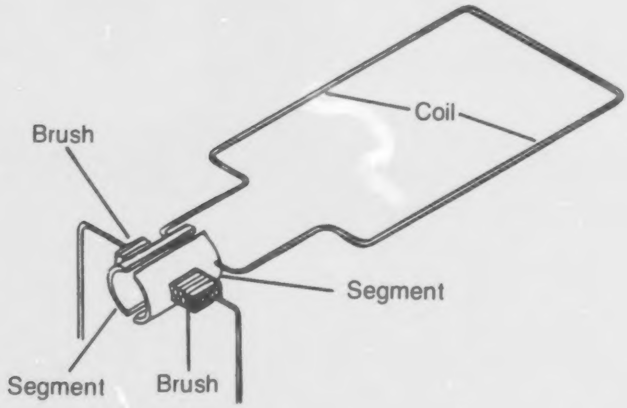
Prony Brake


Fixed Scale Anchor
Scale
(Pounds) (F)
Vibration
Filter
Friction
Adjustment
Torque
Arm
Rotation Pulley
Brake
Blocks
or Band
Force Radius
D in Feet

Torque = FXD

Basic DC Motor


Field Magnet
Magnetic Field of Coil
Rotation
Commutator
+
-
Coil
S
N
Field Magnet
Brushes


Brush
Coil
Segment
Segment
Brush

Commutator Assembly

MOTORS
UNIT XIV

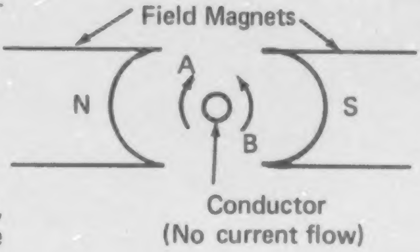
ASSIGNMENT SHEET #1--DETERMINE THE DIRECTION OF INDUCED MAGNETIC FIELDS, INDUCED CURRENTS, AND MOTOR ACTION CAUSED BY INDUCTION

1. If the conductor in Figure 1 moves upward, which arrow, a or b, indicates the direction of the induced magnetic field?

   a. _____ (clockwise)

   b. _____ (counterclockwise)

FIGURE 1


Field Magnets
A
B
N
S
Conductor
(No current flow)

2. If the conductor in Figure 1 moves downward, which arrow, a or b, indicates the direction of the induced magnetic field?

   a. _____

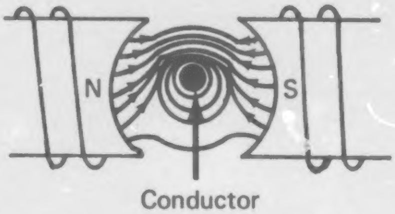
   b. _____

3. In Figures 2 and 3, current is flowing through the conductor. In Figure 3, in which direction will the conductor move?

   a. _____ upward

   b. _____ downward

FIGURE 2

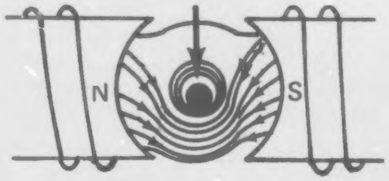

N
S
Conductor

4. In Figure 3, in which direction will the conductor move?

   a. _____ upward

   b. _____ downward

FIGURE 3



5. In Figure 4, the armature coil will turn

   a. _____ clockwise

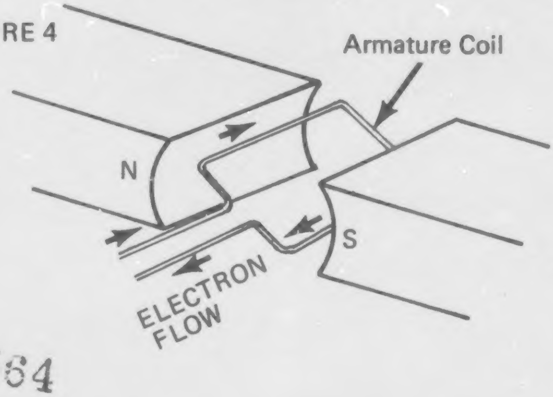
   b. _____ counterclockwise

6. In Figure 5, the armature coil will turn

   a. _____ clockwise

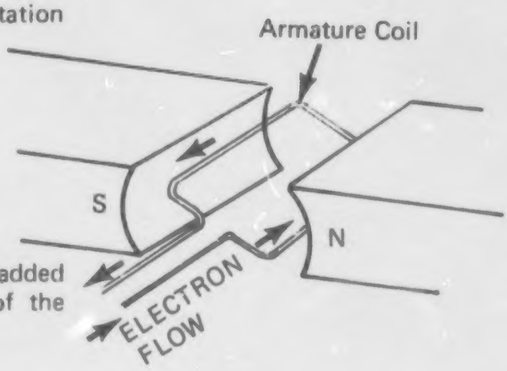
   b. _____ counterclockwise

FIGURE 4


Armature Coil
N
S
ELECTRON FLOW

ASSIGNMENT SHEET #1

FIGURE 5



7. In Figures 4 and 5, if the current through the armature coil is increased, the speed of rotation of the coil will

   a. ______ decrease

   b. ______ remain the same

   c. ______ increase

8. In Figures 4 and 5, if additional loops are added to the armature coil, the speed of rotation of the armature will

   a. ______ decrease

   b. ______ increase

   c. ______ remain the same

MOTORS
UNIT XIV

ASSIGNMENT SHEET #2--CALCULATE MOTOR POWER AND EFFICIENCY

1. Convert the following motor inputs (voltage/current) to input power (watts):

   a. Input voltage -- 115 volts
   Input current -- 10 amps
   Input power -- ____________ watts

   b. Input voltage -- 230 volts
   Input current -- 25 amps
   Input power -- ____________ watts

2. Convert the following motor outputs (horsepower) to output power (watts):

   a. Motor output -- 7 hp
   Output power -- ____________ watts

   b. Motor output -- 3.5 hp
   Output power -- _______ watts

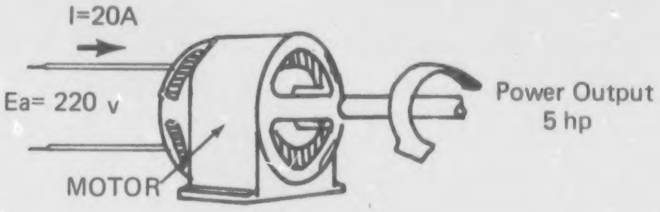
3. Calculate the efficiency of the following motors:

   a. Input power -- 2200 watts
   Output power -- 1500 watts
   Efficiency -- ____________ %

   b. Input power -- 1500 watts
   Output power -- 1000 watts
   Efficiency -- ____________ %

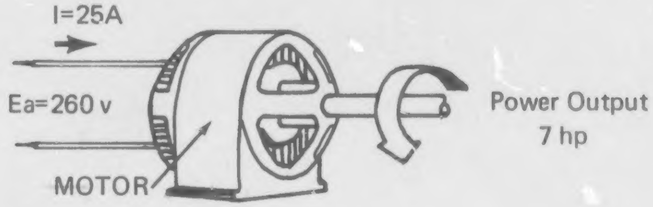
4. Calculate the efficiency of the motors shown below:

   a.



Efficiency = ______________________ %

   b.



Efficiency = ______________________ %

ASSIGNMENT SHEET #2

5. A 3-hp motor has an efficiency rating of 80% and operates with 110 volts input. How much current (to nearest amp) will it draw at full load? ____________amps

6. When operating at full load, a 75% efficient motor draws 20 amps from a 220-volt source. What is the motor's horsepower rating? ____________hp (to the nearest tenth)

MOTORS
UNIT XIV

ASSIGNMENT SHEET #3--MATCH MOTOR TORQUE AND ELECTRON FLOW WITH DIRECTIONAL ARROWS

Directions: Match the motor torque and electron flow directional arrows in the right column with the proper items in the left column.

_____a. Figure 1, movement of conductor A

_____b. Figure 1, movement of conductor B

_____c. Figure 1, direction of loop rotation

_____d. Figure 2, movement of conductor A

_____e. Figure 2, movement of conductor B

_____f. Figure 2, direction of loop rotation

_____g. Figure 3, direction of electron flow, conductor A

_____h. Figure 3, direction of electron flow, conductor B

1. Clockwise rotor rotation ↷
2. Downward movement ⇩
3. Right move-movement →
4. Counterclockwise rotor rotation ↶
5. Left movement ←
6. Upward movement ⇧

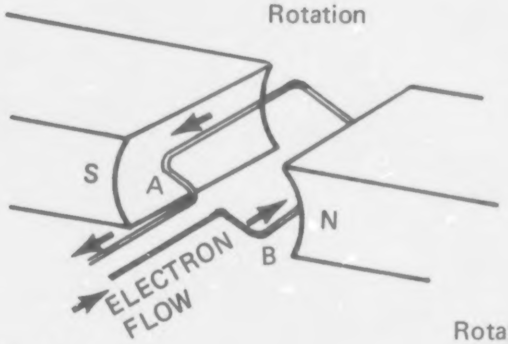

Rotation
S
A
N
B
ELECTRON
FLOW

Figure 1

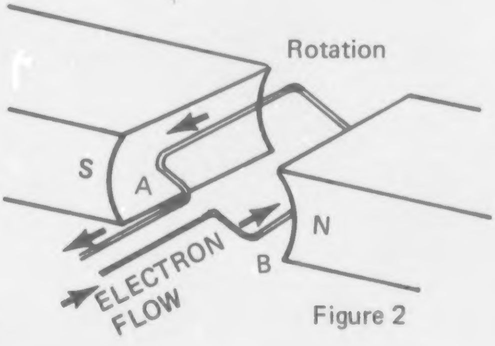

Rotation
S
A
N
B
ELECTRON
FLOW

Figure 2

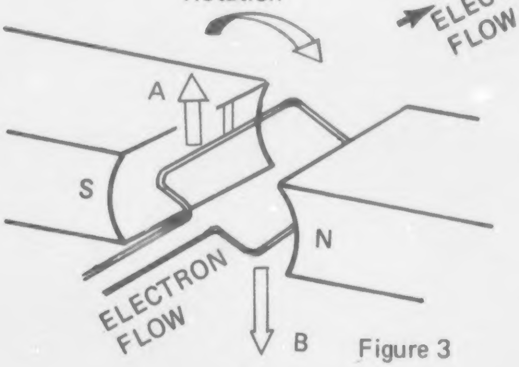

Rotation
A
S
N
ELECTRON
FLOW
B

Figure 3

MOTORS
UNIT XIV

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

1. a
2. b
3. b
4. a
5. a
6. a
7. c
8. b

Assignment Sheet #2

1. a. 1150 watts
   b. 5750 watts

2. a. 5222 watts
   b. 2611 watts

3. a. 68%
   b. 67%

4. a. 85%
   b. 80%

5. 25 amps

6. 4.4 hp

Assignment Sheet #3

a. 6
b. 2
c. 1
d. 2
e. 6
f. 4
g. 5
h. 3

MOTORS
UNIT XIV

JOB SHEET #1--PRODUCE MOTOR ACTION FROM A CURRENT-CARRYING CONDUCTOR IN A MAGNETIC FIELD

I. Tools and materials

   A. Two bar magnets

   B. 1 1/2 volt dry cell

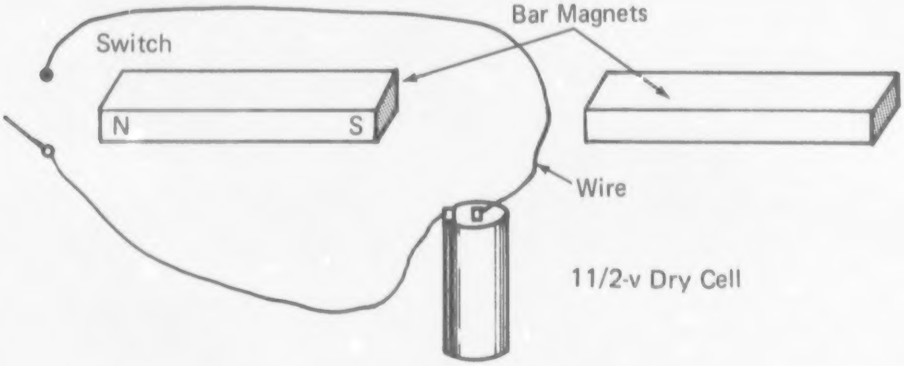
   C. 2 feet of stranded #26 copper wire

   D. Switch

II. Procedure

   A. Set up the experiment as shown in Figure 1

FIGURE 1


Bar Magnets
Switch
N
S
Wire
11/2-v Dry Cell

JOB SHEET #1

B. Make sure the magnets are aligned with opposite poles facing each other

C. Position the wire between the magnets so that it is in the center of and perpendicular to the magnetic field between the two opposite poles

D. Close the switch and reopen after one second

(NOTE: The wire jumps when the switch is closed and returns to its original position when the switch is reopened.)

E. Turn one magnet around so that like poles are facing each other

F. Close the switch and reopen after one second

(NOTE: The wire does not move.)

G. Reverse one of the magnets so that opposite poles again face each other

H. Close the switch and reopen after one second

(NOTE: The wire jumps when the switch is closed, but in the opposite direction of movement in step D. It returns to its original position when the switch is reopened.)

I. Draw an arrow on Figure 3, around the conductor where it passes between the magnets, to show the direction of the magnetic lines of the conductor

(NOTE: The following questions may be used for discussion:

1. Why did the wire jump when the switch was closed in steps D and H?
2. Why did the wire not move when the switch was closed in step F?
3. In which direction did the wire move when the switch was closed in step D? Why?
4. In which direction did the wire move when the switch was closed in step H? Why?)

MOTORS
UNIT XIV

JOB SHEET #2--CALCULATE HORSEPOWER OF A SMALL MOTOR

I. Tools and materials

A. Small 12V DC motor (hobby type)

B. 12V DC power supply

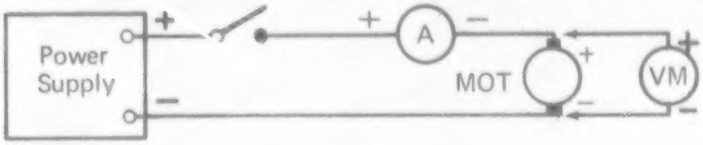
C. SPST switch

D. Multimeter

E. Milliammeter

II. Procedure

A. Connect the motor and meters as shown in the following schematic



B. Adjust the power supply for 12V output as indicated on the voltmeter

C. Close the switch

D. Readjust the power supply if necessary for 12V output

E. Read and record the current required for the motor under no-load

Current ______________________________

F. Apply load to motor by grasping shaft between thumb and finger but do not stop the motor

G. Read and record the voltage input and the current input to the motor under this load condition

Current ______________________ Voltage ______________________

H. Assume a motor of 100% efficiency and calculate the no-load horsepower (Step E) and the load horsepower (Step G)

$HP_{(No\text{-}load)}$ = ____________________ $HP_{(Load)}$ = ____________________

JOB SHEET #2

(NOTE: The following questions may be used for discussion:

1. Is there a difference between no-load and load HP calculations? Why?
2. Did the input voltage (12V) change when the motor was loaded? Why?
3. This job measures the input power. Discuss how actual output power could be measured.)

MOTORS
UNIT XIV

NAME ______________________________

TEST

1. Match the terms on the right with their correct definitions.

______a. A system of rating motors; the rated power

______b. A device that converts electrical energy into mechanical energy

______c. Right angle movement of a conductor in a magnetic field

______d. Unit of measure of force

______e. Force in a rotational direction

______f. An instrument for measuring torque

______g. The rotating part of a DC motor

______h. The magnetic flux in a motor

______i. A cylinder on the armature of two or more segments connected to the coils of a motor

______j. Conductive material providing electrical connection to the coils of a motor

______k. Stationary part of a motor housing the armature

______l. Rotating member of an electrical machine that has a shaft

1. Motor action
2. Horsepower
3. Torque
4. Armature
5. Prony brake
6. Rotor
7. Motor
8. Brushes
9. Field
10. Stator
11. Commutator
12. Foot pounds

2. Discuss the direction of magnetic field flow surrounding a conductor.

a.

b.

3. Select true statements concerning the requirements for motor action by placing an "X" in the appropriate blanks.

______a. Magnetic field lines always flow from south to north poles

______b. Magnetic field density is always determined by the field strength

______c. The conductor field distorts the magnetic field ______d. The resultant magnetic field is weakest where the two combine

______e. Conductor moves away from the stronger magnetic field

______f. Conductor moves at 100° angles to the magnetic field

4. Discuss the production of motor torque.

5. List four methods of increasing motor torque.

   a.

   b.

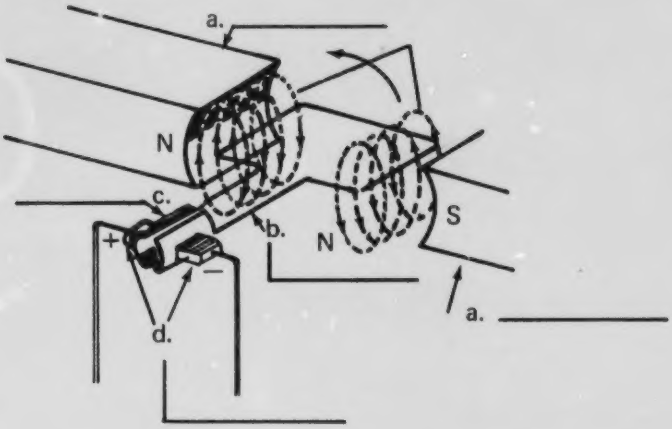
   c.

   d.

6. Discuss factors which determine motor efficiency.

7. State the formula for determining motor efficiency.

8. Identify basic parts of a DC motor.



9. Determine the direction of induced magnetic fields, induced currents, and motor action caused by induction.

10. Calculate motor power and efficiency.

11. Match motor torque and electron flow with directional arrows.

12. Demonstrate the ability to:

    a. Produce motor action from a current-carrying conductor in a magnetic field.

    b. Calculate horsepower of a small motor.

    (NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

MOTORS
UNIT XIV

ANSWERS TO TEST

1.

a.	2	e.	3	i.	11
b.	7	f.	5	j.	8
c.	1	g.	4	k.	10
d.	12	h.	9	l.	6

2. Discussion should include:

   a. Field is clockwise when current flows toward you
   b. Field is counterclockwise when current flows away from you

3. b, c, e

4. Discussion should include:

   a. Looped wire attached to shaft
   b. Magnetic field
   c. One side of loop forced upward and other side downward
   d. Result is rotational action

5. Any four of the following:

   a. Use more than one coil
   b. Decrease air gap in coils
   c. Use magnetic material to support coils
   d. Increase coil current
   e. Increase magnetic field strength
   f. Increase length of coil

6. Discussion should include:

   a. Input power (P_I)

      1. Usually measured in watts
      2. Determined by multiplying input voltage by input current (E x I)

   b. Output power (P_O)

      1. Usually measured in horsepower by a prony brake
      2. Convert horsepower to watts by multiplying by 746

7. Efficiency (in percent) = $\frac{\text{Output power}}{\text{Input power}} \times 100$ or $\frac{P_O}{P_I} \times 100$

8. a. Field magnets
   b. Armature or coil
   c. Commutator
   d. Brushes

9. Evaluated to the satisfaction of the instructor.
10. Evaluated to the satisfaction of the instructor.
11. Evaluated to the satisfaction of the instructor.
12. Performance skills evaluated to the satisfaction of the instructor.

THE NATURE OF ALTERNATING CURRENT
UNIT I

UNIT OBJECTIVE

After completion of this unit, the student should be able to determine sine wave relationships and conversions, and compute instantaneous sine wave values, periods and wavelengths. The student should also be able to construct a sine wave cycle. This knowledge will be evidenced by correctly performing the procedures outlined on the assignment and job sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms associated with the nature of alternating current to correct definitions.
2. Select true statements regarding sine wave relationships.
3. Complete a sine wave value conversions chart.
4. Match the abbreviations with the correct descriptions of terms relating to alternating current waves.
5. List the formulas used to compute instantaneous values of voltage and current.
6. Match sine functions with commonly used values.
7. Distinguish between audio, sonic, radio, and ultrasonic frequencies.
8. Select true statements regarding frequency, period, and wavelength.
9. Determine sine wave relationships.
10. Determine sine wave conversions.
11. Compute instantaneous sine voltage values.
12. Compute period and wavelength.
13. Demonstrate the ability to construct a sine wave cycle.

THE NATURE OF ALTERNATING CURRENT
UNIT I

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information, assignment, and job sheets.

III. Make transparency.

IV. Discuss unit and specific objectives.

V. Discuss information and assignment sheets.

VI. Demonstrate and discuss the procedures outlined in the job sheets.

VII. Display and discuss the frequency spectrum.

VIII. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:
  - A. Objective sheet
  - B. Information sheet
  - C. Transparency Master #1--Sine Wave Relationships
  - D. Assignment sheets
    1. Assignment Sheet #1--Determine Sine Wave Relationships
    2. Assignment Sheet #2--Determine Sine Wave Conversions
    3. Assignment Sheet #3--Compute Instantaneous Sine Voltage Values
    4. Assignment Sheet #4--Compute Period and Wavelength
  - E. Answers to assignment sheets
  - F. Job Sheet #1--Construct a Sine Wave Cycle
  - G. Test
  - H. Answers to test

II. References--Grob, Bernard. *Basic Electronics.* 5th ed., New York: McGraw-Hill Book Co., 1977.

THE NATURE OF ALTERNATING CURRENT
UNIT I

INFORMATION SHEET

I. Terms and definitions

A. Alternation--Moving from zero to a maximum (or minimum) and back to zero

(NOTE: One complete cycle of AC has two alternations.)

B. Amplitude--The magnitude of voltage or current at a specific time

C. Cycle--The series of values of a periodic quantity that occurs during one period

(NOTE: One cycle is one complete set of positive and negative values of an alternating current.)

D. Frequency--Number of cycles completed in one second

E. Period--Time required to complete one cycle

F. Hertz--The measure of frequency equal to the number of cycles per second

G. Electrical degree--1/360th of a cycle

H. Radian--Angular part of a circle or cycle which includes an arc equal to the radius

(NOTE: 360 degrees equals 2 π radians--thus, 1 radian equals 57.3 degrees.)

I. Peak amplitude--Maximum value of an alternation

J. Sine wave average value--.637 times the peak value

(NOTE: Average value of a complete sine wave cycle is zero.)

K. Sine wave effective value--.707 times the peak value

(NOTE: This is the value of AC equal to its DC equivalent value.)

L. Sine wave RMS (root-mean-square) value--Equals the effective value

M. Peak-to-peak value--Twice the peak or maximum value of an alternation

N. Wavelength--Distance a wave travels in one cycle

INFORMATION SHEET

II. Sine wave relationships (Transparency 1)

- A. Degrees and radians (conversions)
  - 1. 2 π radians equals 360 degrees
  - 2. π radians equals 180 degrees
  - 3. $\pi/3$ radians equals 180/3 degrees or 60 degrees, thus π/n radians equals 180/n degrees
- B. Cycles and radians--One cycle equals 2 π radians
- C. Alternation and radians--One alternation equals π radians
- D. Alternation and degrees--One alternation equals 180 degrees
- E. Alternation peak value--Equals the maximum value during a positive alternation and the most minimum value during a negative alternation
- F. Effective value and peak value--The effective value is obtained by multiplying the peak value by .707
- G. Peak-to-peak value and peak value--The peak-to-peak value equals two times the peak value

III. Sine wave value conversions

FROM	TO			
	EFFECTIVE	AVERAGE	PEAK	PEAK-TO-PEAK
EFFECTIVE (RMS)	1.0	0.900	1.414	2.828
AVERAGE	1.110	1.0	1.571	3.142
PEAK	0.707	0 .637	1.0	2.000
PEAK-TO-PEAK	0.354	0.318	0.500	1.0

IV. Abbreviations of terms relating to alternating current waves

- A. E_{max} = Maximum voltage
- B. I_{max} = Maximum current
- C. e = Instantaneous value of voltage
- D. i = Instantaneous value of current
- E. E = RMS or effective value of voltage
- F. I = RMS or effective value of current

INFORMATION SHEET

- G. T or t = Time (used with period)
- H. λ = Wavelength
- I. f = Frequency
- J. Hz = Hertz

V. Formulas to compute instantaneous voltage and current values

- A. $e = E_{max} \sin \theta$ (where θ is the angular displacement)
- B. $i = I_{max} \sin \theta$

VI. Commonly used values and sine function

- A. Sin 0° = 0
- B. Sin 30° = .5
- C. Sin 45° = .707
- D. Sin 60° = .866
- E. Sin 90° = 1
- F. Sin 180° = 0
- G. Sin 270° = -1
- H. Sin 360° = 0

  (NOTE: Sin 360° = Sin 0°.)

VII. Frequency groupings

- A. Audio
  1. Frequencies corresponding to normally audible sound waves
  2. Frequencies range roughly from 15 Hz to 20,000 Hz
  3. Electrically produced
- B. Sonic
  1. Frequencies corresponding to normally audible sound waves
  2. Frequencies range roughly from 15 Hz to 20,000 Hz
  3. Mechanically produced

INFORMATION SHEET

C. Radio

1. Frequencies above the audio range
2. Frequencies range roughly from 10 KHz to 100,000 MHz
3. Electrically produced

D. Ultrasonic

1. Frequencies above the audio or sonic range
2. Mechanically produced

VIII. Frequency, period, and wavelength

A. Relationships given by formula $T = 1/f$ (or $f = 1/T$) where T is time in seconds of a period, and f is frequency in hertz

B. Velocity of transmission (v)

1. Electrical waves travel faster than sound waves

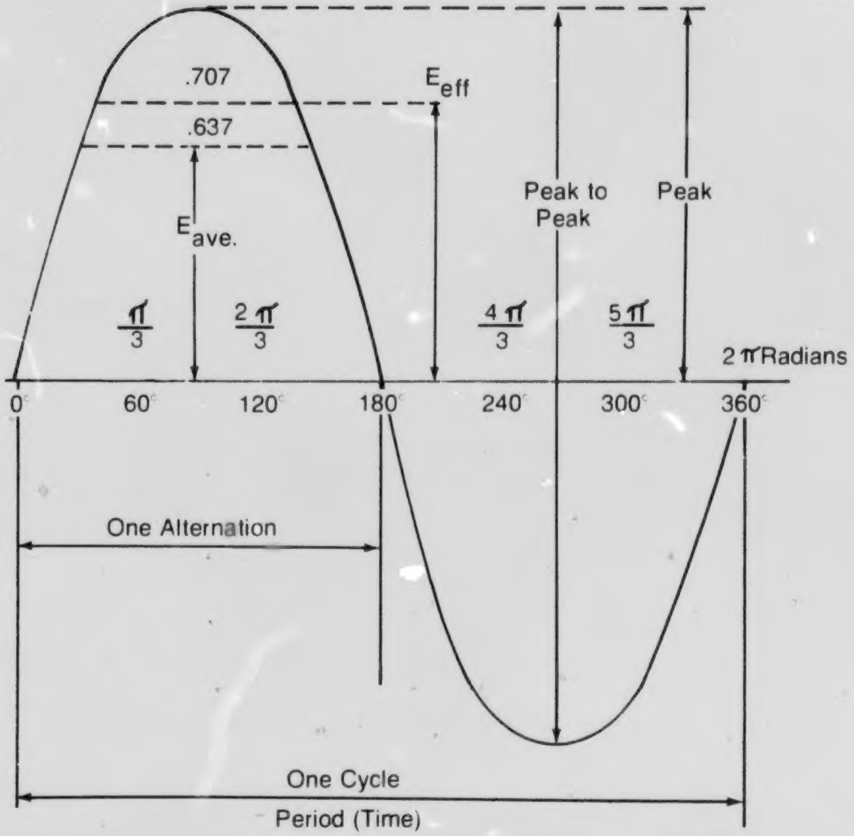
   (NOTE: Electrical waves travel approximately at the speed of light; 186,000 miles per hour or 300,000 kilometers per second.)

2. Sound waves travel much slower than do electrical waves

   (NOTE: Sound waves travel approximately at 760 miles per hour or 332 meters per second in air.)

C. Wavelength (λ) equals the velocity divided by the frequency in hertz $\left(\frac{v}{f}\right)$ thus, wavelength varies directly with velocity and wavelength varies inversely with frequency

Sine Wave Relationships


.707
.637
E_{eff}
$E_{ave.}$
Peak to Peak
Peak
$\frac{\pi}{3}$
$\frac{2\pi}{3}$
$\frac{4\pi}{3}$
$\frac{5\pi}{3}$
2π Radians
0°
60°
120°
180°
240°
300°
360°
One Alternation
One Cycle
Period (Time)

THE NATURE OF ALTERNATING CURRENT
UNIT I

ASSIGNMENT SHEET #--DETERMINE SINE WAVE RELATIONSHIPS

1. Complete the blanks with the correct relationship between degrees and radians. (NOTE: π radians = 180°.)

	Degrees	Radians
a.	360	_______
b.	90	_______
c.	60	_______
d.	45	_______
e.	_______	0
f.	_______	π
g.	_______	2π
h.	_______	$\pi/2$

2. One cycle equals_______radians.
3. _______radians equals one alternation.
4. One alternation equals_______degrees.
5. Describe the peak value of a sine wave.
6. The effective voltage or rms voltage equals_______times the peak value.
7. What is the difference between peak value and peak-to-peak value?

THE NATURE OF ALTERNATING CURRENT
UNIT I

ASSIGNMENT SHEET 2--DETERMINE SINE WAVE CONVERSIONS

1. An oscilloscope shows that the peak voltage value of an AC wave is 155.6 volts. What is the voltage that would be read on the AC scale of a multimeter (i.e., RMS voltage value)?

   Answer:________________

2. If your voltmeter reads 25 volts (effective value), what would be the peak voltage shown on an oscilloscope (peak value)?

   Answer:________________

3. In problem 2, what would the peak-to-peak voltage be?________________

4. If the peak value of a sine wave is 100, the average value of one alternation is ________________.

THE NATURE OF ALTERNATING CURRENT
UNIT I

ASSIGNMENT SHEET 3--COMPUTE INSTANTANEOUS SINE VOLTAGE VALUES

Using the formula $e = E_{max} \sin \theta$, compute the instantaneous values of a sine wave which has a maximum value of 90 volts for the following angular positions.

1. 30°, e = _______
2. 45°, e = _______
3. 60°, e = _______
4. 90°, e = _______
5. 270°, e = _______
6. 2π, e = _______
7. π, e = _______
8. $(\pi/2)$, e = _______
9. $(3\pi/4)$, e = _______
10. $(4\pi/3)$, 3 = _______

THE NATURE OF ALTERNATING CURRENT
UNIT I

ASSIGNMENT SHEET 4--COMPUTE PERIOD AND WAVELENGTH

Directions: Formulas:

$$T = \frac{1}{f}$$

$$f = \frac{1}{t}$$

$$\lambda = \frac{v}{f} = \frac{v}{1/t} \quad \text{or} \quad vt$$

$$f = \frac{v}{d}$$

(NOTE: Radio waves have a velocity of 3×10^{10} cm/s or 186,000 miles/s.)

1. How much time is required for a 60 cycle per second (60 Hz) voltage to complete one cycle?____________seconds.
2. If one cycle requires 1/400th of a second, the frequency is____________Hz.
3. If you increase frequency, the time required for one cycle will (increase) (decrease).
4. A radio station transmits on a frequency of 780 kilohertz. The wavelength is ____________.
5. Some amateur radio operators have transmitters operating in the 10-meter band. Approximately what frequency are they using?

   Answer:____________________
6. A radio amateur operating on a wavelength of 80 meters is transmitting at a (higher) (lower) frequency than one operating on 20 meters.
7. A 100 MHz wave has a wavelength of____________cm.
8. If you increase frequency, the wavelength is (increased) (decreased).
9. 3×10^{10} cm/s equals____________meters per second.
10. 186,000 miles per second equals____________miles per hour.

THE NATURE OF ALTERNATING CURRENT
UNIT I

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

1. a. 2π
   b. $\pi/2$
   c. $\pi/3$
   d. $\pi/4$
   e. 0 or 360
   f. 180
   g. 360
   h. 90
2. 2π
3. π
4. 180
5. The maximum value during one alternation
6. .707
7. Peak value is one-half the peak-to-peak value

Assignment Sheet #2

1. 110 volts
2. 35.35 volts
3. 70.7 volts
4. 63.7

Assignment Sheet #3

1. 45 (All units are volts)
2. 63.64
3. 77.94
4. 90
5. -90
6. 0
7. 0
8. 90
9. 63.64
10. -77.94

Assignment Sheet #4

1. 1/60 second
2. 400 Hz.
3. decrease
4. 3.846×10^4 cm. (or equivalent)
5. 30 MHz.
6. lower
7. 300
8. decreased
9. 3×10^8
10. 6.696×10^8 (or 669,600,000)

THE NATURE OF ALTERNATING CURRENT
UNIT I

JOB SHEET #1--CONSTRUCT A SINE WAVE CYCLE

I. Tools and materials

A. Graph paper

B. Compass

C. Protractor

D. Ruler

E. Calculator (or square root tables)

II. Procedure

A. Draw a circle with a radius of 10 graph paper units on the extreme left side of your graph paper

B. Draw the diameter of the circle and extend it across the graph paper

C. Draw the tangent to the circle on the right end of the diameter line

D. Mark off 15 degree increments from zero to 360 degrees letting the diameter line be the zero degree mark (Figure 1).

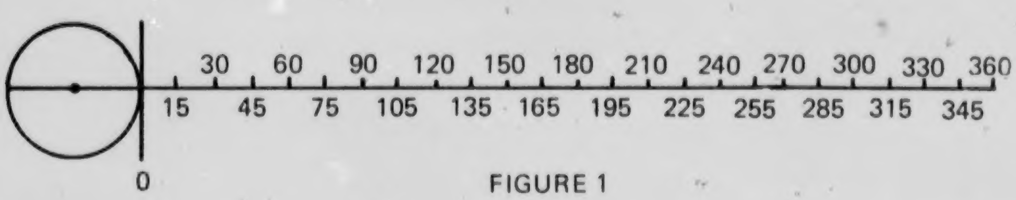


FIGURE 1

E. Use your protractor and mark off the upper half of your circle in 15 degree increments.

(NOTE: Carefully mark the intersection of each 15 degree line and the circle.)

F. Measure the vertical distance from the base line to the 15-degree line intersection with your compass and transfer this distance to the 15 degree mark to the right and repeat for each 15 degree mark

JOB SHEET #1

G. Make a table of the degrees versus the vertical distances letting the maximum vertical distance be one.

(NOTE: All other distances will be less than one, and one is at the 90 degree position.)

H. Make a smooth curve between the points plotted to the right of the circle

(NOTE: This will be the graph of a sine-wave cycle.)

I. Compute the average vertical height of one alternation by adding the heights you have in one alternation and dividing by the number of heights

J. Use the table and square each height, then compute the average of these squared heights

(NOTE: Add all the squared heights and divide by the number you have.)

K. Calculate the square root of the average squared height obtained in Step J which will result in the RMS value

(NOTE: Use your calculator or use a square root table.)

L. Discuss with your instructor how your computations compare with an AC voltage having a maximum value (peak value) of one volt

THE NATURE OF ALTERNATING CURRENT
UNIT I

NAME______________________________

TEST

1. Match the terms on the right to the correct definitions.

______ a. Equals the effective value

______ b. Maximum value of an alternation

______ c. The measure of frequency equal to the number of cycles per second

______ d. The series of values of a periodic quantity that occurs during one period

______ e. Moving from zero to a maximum (or minimum) and back to zero

______ f. Number of cycles completed in one second

______ g. Angular part of a circle or cycle which includes an arc equal to the radius

______ h. .707 times the peak value

______ i. Distance a wave travels in one cycle

______ j. The magnitude of voltage or current at a specific time

______ k. Time required to complete one cycle

______ l. Twice the peak or maximum value of an alternation

______ m. 1/360th of a cycle

______ n. .637 times the peak value

1. Alternation
2. Amplitude
3. Cycle
4. Frequency
5. Period
6. Hertz
7. Electrical degree
8. Radian
9. Peak amplitude
10. Sine wave average value
11. Sine wave effective value
12. Sine Wave RMS (root-mean-square) value
13. Peak-to-peak value
14. Wavelength

2. Select true statements regarding sine wave relationships by placing an "x" in the appropriate blanks.

______ a. The alternation peak value equals the maximum value during a positive alternation and the most minimum value during a negative alternation

______ b. One cycle equals 2 π radians

______ c. One alternation equals π radians

______ d. $\pi/4$ radians equals 180 degrees _____e. π radians equals 180 degrees

_____f. One alternation equals 360 degrees

_____g. The peak value is obtained by multiplying the effective value by .707

_____h. The peak-to-peak value equals two times the peak value

3. Complete the following chart on sine wave value conversions.

FROM	TO			
	EFFECTIVE	AVERAGE	PEAK	PEAK-TO-PEAK
EFFECTIVE (RMS)	1.0	0.900	c._____	e._____
AVERAGE	1.110	1.0	1.571	3.142
PEAK	a._____	b._____	1.0	2.000
PEAK-TO-PEAK	0.354	0.318	d._____	1.0

4. Match the abbreviations relating to alternating current waves to the correct descriptions.

_____a. Wavelength	1. E_{max}
_____b. Instantaneous value of current	2. I_{max}
_____c. Hertz	3. e
_____d. RMS or effective value of current	4. i
_____e. Maximum current	5. E
_____f. Frequency	6. I
_____g. Maximum voltage	7. T or t
_____h. Instantaneous value of voltage	8. λ
_____i. RMS or effective value of voltage	9. f
_____j. Time (used with period)	10. Hz

5. List the formulas used to compute instantaneous values of voltage and current.

a. e = _______________

b. i = _______________

6. Match commonly used values on the right to the correct sine functions.

(NOTE: Some answers will be used more than once.)

_____ a. Sin 0°
_____ b. Sin 30°
_____ c. Sin 45°
_____ d. Sin 60°
_____ e. Sin 90°
_____ f. Sin 180°
_____ g. Sin 270°
_____ h. Sin 360°

1. 0
2. 1
3. -1
4. .5
5. .866
6. .707

7. Distinguish between audio, sonic, radio, and ultrasonic frequencies by placing an "a" next to the audio, an "s" next to the sonic, an "r" next to the radio, and a "u" next to the ultrasonic descriptions of frequencies.

(NOTE: Some descriptions will apply to more than one frequency.)

_____ a. Frequencies range roughly from 15 Hz to 20,000 Hz
_____ b. Frequencies above the audio or sonic range
_____ c. Electrically produced
_____ d. Frequencies above the audio range
_____ e. Mechanically produced
_____ f. Frequencies range roughly from 10KHz to 100,000 MHz
_____ g. Frequencies corresponding to normally audible sound waves

8. Select the true statements regarding frequency, period, and wavelength by placing an " X" in the appropriate blanks.

_____ a. Frequency and time vary inversely with each other
_____ b. Sound waves travel at higher velocities than do electrical waves
_____ c. Wavelength equals velocity divided by frequency
_____ d. Wavelength varies inversely with frequency
_____ e. Wavelength varies inversely with velocity

9. Determine sine wave relationships.
10. Determine sine wave conversions.
11. Compute instantaneous sine values.
12. Compute period and wavelength.
13. Demonstrate the ability to construct a sine wave cycle.

(NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

THE NATURE OF ALTERNATING CURRENT
UNIT I

ANSWERS TO TEST

1.

a.	12	h.	11
b.	9	i.	14
c.	6	j.	2
d.	3	k.	5
e.	1	l.	13
f.	4	m.	7
g.	8	n.	10

2. a, b, c, e, h

3.

a.	0.707
b.	0.637
c.	1.414
d.	0.500
e.	2.828

4.

a.	8	f.	9
b.	4	g.	1
c.	10	h.	3
d.	6	i.	5
e.	2	j.	7

5. a. $e = E_{max} \sin \theta$

   b. $i = I_{max} \sin \theta$

6.

a.	1	e.	2
b.	4	f.	1
c.	6	g.	3
d.	5	h.	1

7.

a.	a, s	e.	s, u
b.	u	f.	r
c.	a, r	g.	a, s
d.	r, u		

8. a, c, d

9. Evaluated to the satisfaction of the instructor

10. Evaluated to the satisfaction of the instructor

11. Evaluated to the satisfaction of the instructor

12. Evaluated to the satisfaction of the instructor

13. Performance skills evaluated to the satisfaction of the instructor

AC GENERATION
UNIT II

UNIT OBJECTIVE

After completion of this unit, the student should be able to select true statements concerning electromagnetic induction, generating voltage electromagnetically, the magnitude of generated voltage, elementary cycle generation, and phase angle diagrams. The student should also be able to determine current flow direction, compute AC cycle instantaneous values, and demonstrate the ability to construct a simple generator and identify generator components. This knowledge will be evidenced by correctly performing the procedures outlined on the assignment and job sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTVES

After completion of this unit, the student should be able to:

1. Match terms associated with AC generation with their correct definitions.
2. Select true statements concerning electromagnetic induction.
3. Select requirements for generating voltage electromagnetically.
4. Discuss the left hand generator rule.
5. Select true statements concerning the magnitude of generated voltage.
6. Select true statements concerning elementary cycle generation.
7. Discuss generator construction using an illustration.
8. State two rules concerning DC generator construction.
9. Select true statements concerning voltage phasors or vectors.
10. Select true statements concerning phase angle diagrams.
11. Discuss elements of three-phase power generation.
12. Determine current flow direction.
13. Compute AC cycle instantaneous values.
14. Demonstrate the ability to:
    a. Construct a simple generator.
    b. Identify generator components.

AC GENERATION
UNIT II

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information, assignment, and job sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information and assignment sheets.

VI. Demonstrate and discuss the procedures outlined in the job sheets.

VII. Visit any type of electrical generating plant including emergency types.

VIII. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

  A. Objective sheet

  B. Information sheet

  C. Transparency masters

    1. TM 1--Electromagnetic Induction
    2. TM 2-- The Left Hand Generator Rule
    3. TM 3--Simple AC Generator
    4. TM 4--Generator Construction
    5. TM 5--DC Generator Commutator
    6. TM 6--Voltage Phasor (Vector)
    7. TM 7--Comparison Sinusoidal and Phasor (Vector) Diagrams
    8. TM 8--Three-Phase Power Generation

  D. Assignment sheets

    1. Assignment Sheet #1--Determine Current Flow Direction
    2. Assignment Sheet #2--Compute AC Cycle Instantaneous Values

E. Answers to assignment sheets

F. Job sheets

  1. Job Sheet #1--Construct a Simple Generator

  2. Job Sheet #2--Identify Generator Components

G. Test

H. Answers to test

II. References:

A. Grob, Bernard. *Basic Electronics.* New York: McGraw-Hill, 1977.

B. *IEEE Standard Dictionary of Terms.* New York: John Wiley, 1972.

AC GENERATION
UNIT II

INFORMATION SHEET

I. Terms and definitions

A. Electromagnetic induction--Process of generating voltage in a conductor by means of a magnetic field

B. Induced voltage--Voltage produced in a conductor by a change in magnetic flux

C. Rotor--Rotating member of an electrical machine that has a shaft

(NOTE: The rotor is sometimes called the armature.)

D. Stator--The stationary portion of an electrical machine

E. Generator--Machine which converts mechanical power to electrical power

F. Alternating current--Current that reverses periodically and that has alternating positive and negative values

G. Phasor--A complex number having magnitude and direction

(NOTE: A phasor is also called a vector.)

H. Phase angle--The measure of the progression of a periodic wave in time from a chosen reference

I. Phase difference--The difference in phase between two sinusoidal functions having the same periods

J. Field winding--A winding on an electrical machine which produces an electromagnetic field

K. Slip rings--Metal rings that conduct current into and out of the rotor of an electrical machine

(NOTE: Slip rings are also called collector rings.)

L. Brushes--A carbon conductor connecting the stationary and moving parts of an electrical machine

M. Three-phase circuit--A combination of circuits producing output voltages differing in phase by one-third cycle (120°)

N. Induction--Electrical coupling by a magnetic field

O. Commutator--Metal current-carrying members that are insulated from one another by insulating segments and that make contact with brushes

INFORMATION SHEET

II. Principle of electromagnetic induction (Transparency 1)

  A. Conductor moved through a magnetic field produces voltage in conductor

  B. A magnetic field moved across a conductor produces (induces) voltage in the conductor

  C. This phenomenon is called electromagnetic induction

III. Requirements for generating voltage electromagnetically

  A. Magnetic field

  B. Conductor in the magnetic field

  C. Relative motion between conductor and magnetic field

IV. Left hand generator rule (Transparency 2)

  A. Direction of current induced in conductor depends upon

    1. Direction of motion

    2. Direction of magnetic flux

  B. In the left hand method of determining electron flow direction

    1. Point forefinger in direction of magnetic flux

    2. Point raised thumb in direction of conductor motion

    3. Middle finger (when at right angle to thumb and forefinger) points in direction of current flow in conductor

V. Magnitude of generated voltage (Transparency 3)

  A. The magnitude of induced voltage is proportional to number of flux lines cut per second by conductor

  B. Number of flux lines cut per second by conductor is determined by

    1. Velocity of conductor

    2. Length of conductor

    3. Magnetic field strength

    4. Angle conductor cuts field

    Example: When the conductor moves parallel to lines, no voltage is generated; when conductor moves 90° to lines maximum voltage is generated.

INFORMATION SHEET

VI. Elementary cycle generation (Transparency 3)

- A. Start with no lines being cut to maximum cutting of lines by rotating coil 1/4 turn, from no induced voltage to the maximum induced voltage
- B. Second 1/4 turn changes conductor from position of cutting maximum lines to movement parallel to lines, from maximum voltage to zero
- C. Third 1/4 turn changes conductor from position of no lines being cut to maximum cutting lines but in opposite direction from the first 1/4 turn, from zero voltage to maximum negative voltage
- D. Fourth 1/4 turn changes conductor from maximum cutting of lines to minimum, from maximum negative voltage back to zero; this completes one cycle of AC generated voltage

VII. Generator construction (Transparency 4)

- A. Yoke and base
  1. Pole pieces project from yoke

     (NOTE: This is always an even number.)
  2. Field coils wound on pole pieces
  3. End bells which support
     - a. Brush supports
     - b. Shaft bearings
- B. Armature and slip rings
  1. Consists of many turns of insulated copper wire around a core and shaft
  2. Armature core mounted on shaft which rotates at high speeds
  3. Slip rings connect to ends of core winding
  4. Carbon brushes connect slip rings to external load
  5. Carbon is used because
     - a. Relatively constant contact resistance
     - b. Softness prevents excessive wear

     (NOTE: Many AC generators have the magnetic field rotating and the output in the stator.)

INFORMATION SHEET

VIII. DC generator construction

- A. Same as AC generator except slip rings are replaced with a commutator (Transparency 5)
- B. Commutator action produces a pulsating DC in output circuit

IX. Voltage phasor or vector (Transparency 6)

- A. Length of phasor equals maximum voltage or current generated
- B. Phasor rotates counterclockwise through full 2 pi radians (360°) of the circle
- C. Distance from end of phasor to horizontal base line at a given time equals the value of voltage or current at that time
- D. Phasor solution is graphical equivalent of formulas
    1. $e = E_{max} \sin \theta$ OR
    2. $i = I_{max} \sin \theta$

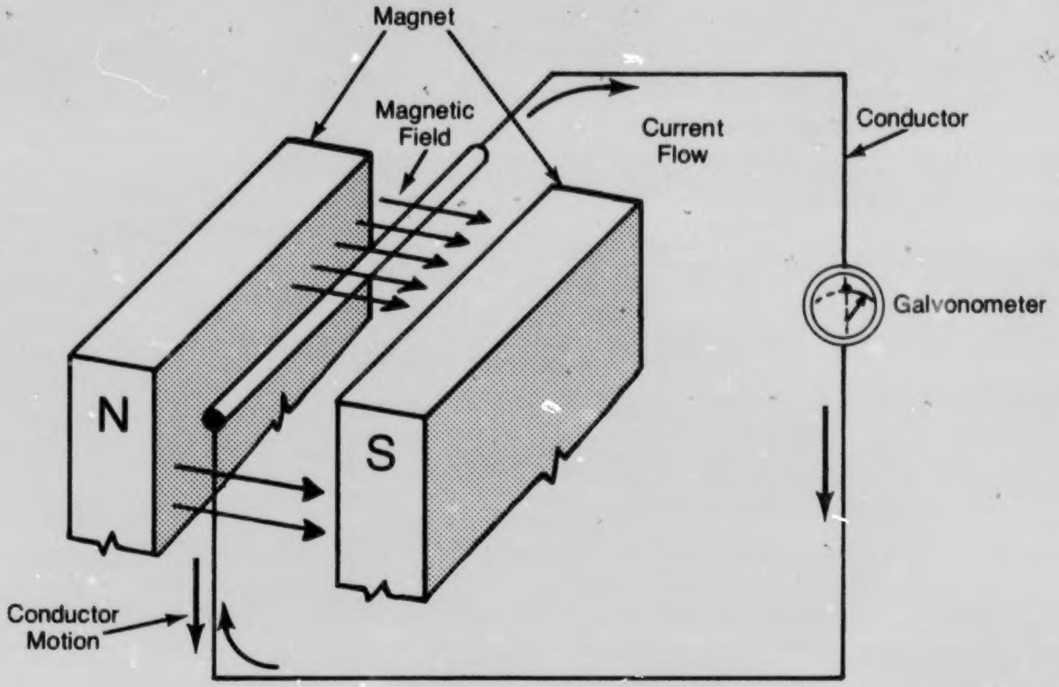
X. Phase angle diagrams (Transparency 7)

- A. Comparison of two or more sinusoidal functions with same periods
- B. Length of phasor arrow represents values of current or voltage
- C. One phasor is drawn at zero degree position as the reference
- D. Other phasor(s) drawn relative in time (or rotational position) to the phasor chosen as reference
- E. Phasor diagrams are equivalent to sinusoidal waveforms

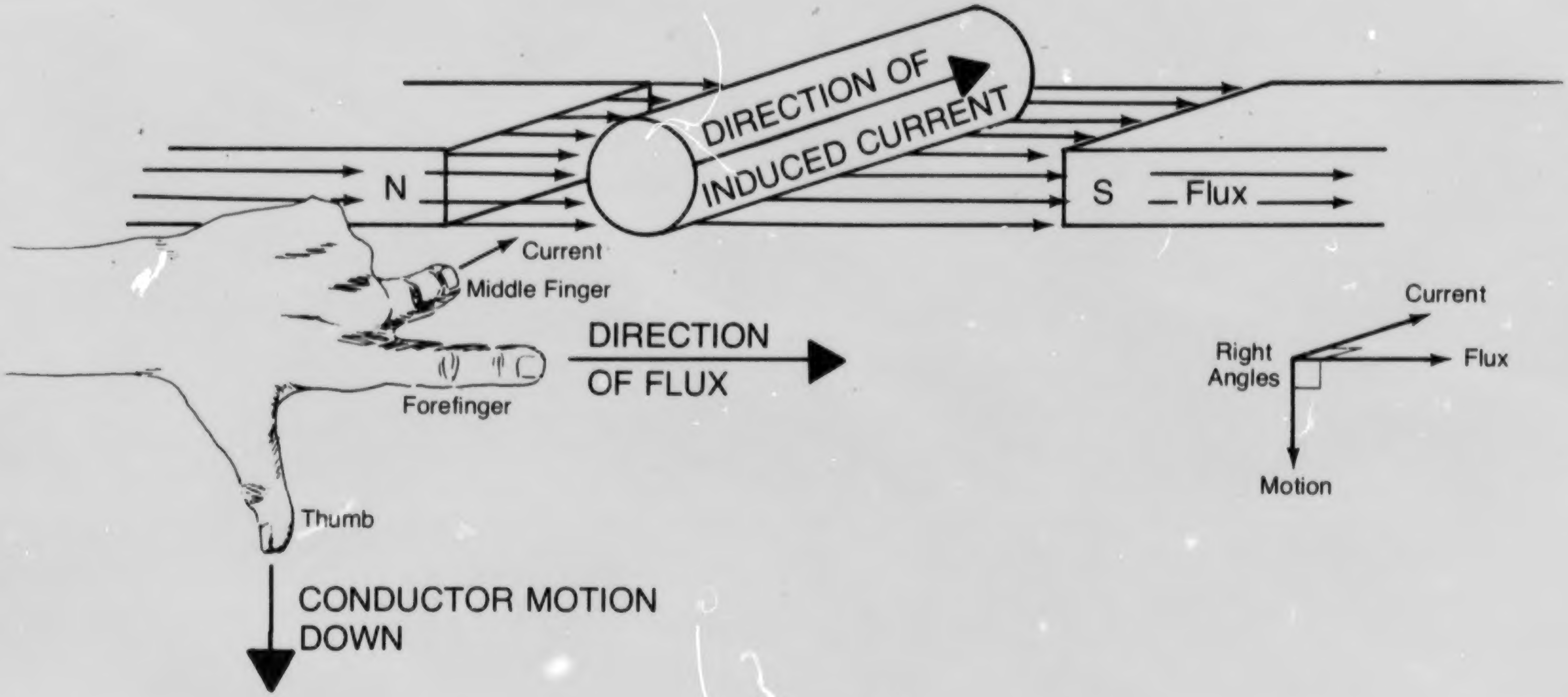
XI. Three-phase power generation (Transparency 8)

- A. Three generator windings equally spaced produces output voltages 120 degrees out of phase with each other (360° / 3)
- B. Different connections possible are
    1. Delta
    2. Wye or star

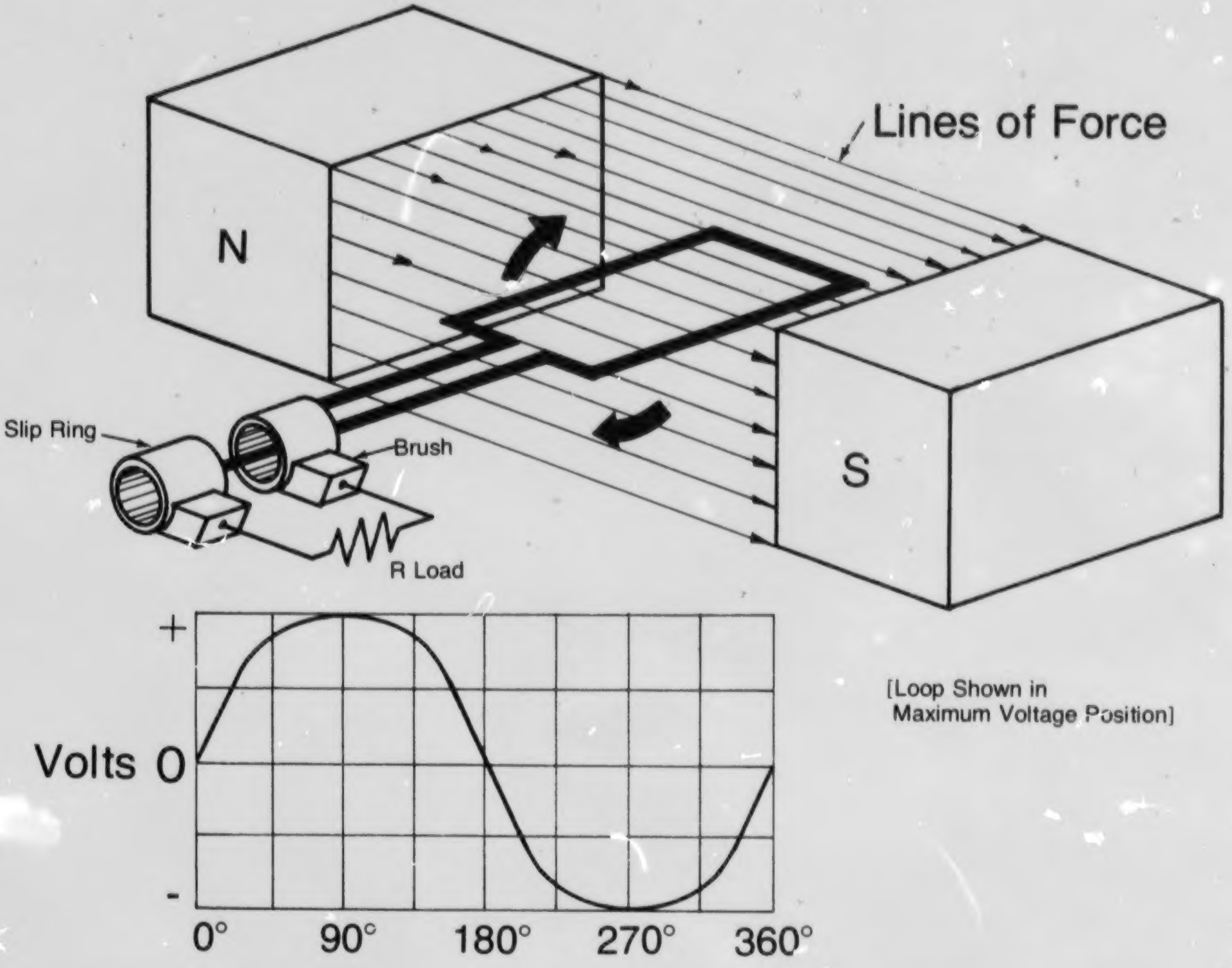
Electromagnetic Induction


Magnet
Magnetic Field
Current Flow
Conductor
Galvonometer
N
S
Conductor Motion

The Left Hand Generator Rule

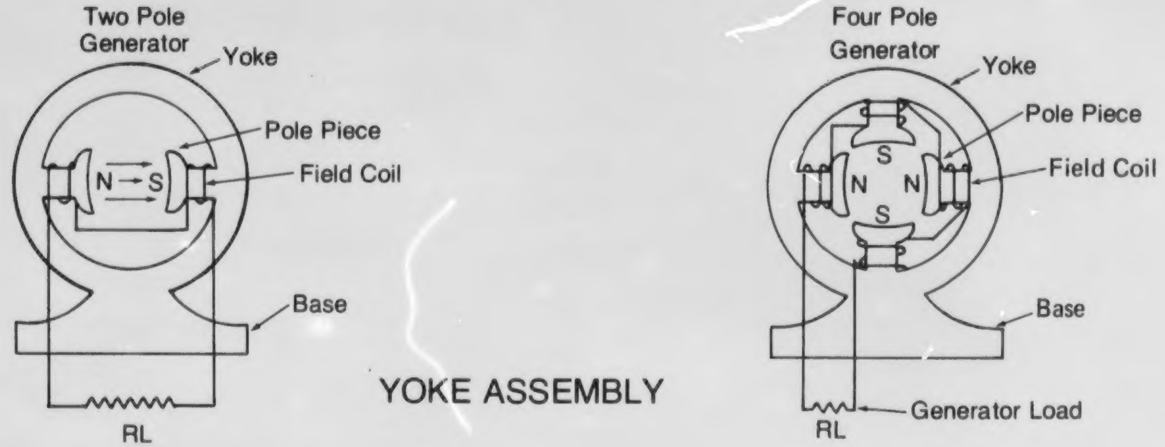

DIRECTION OF INDUCED CURRENT
N
S
Flux
Current
Middle Finger
DIRECTION OF FLUX
Forefinger
Thumb
CONDUCTOR MOTION DOWN
Current
Right Angles
Flux
Motion

Simple AC Generator

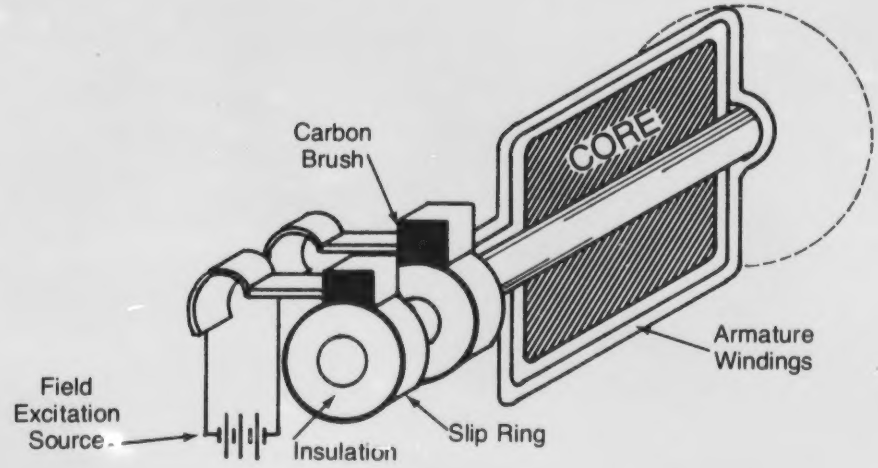

Lines of Force
N
S
Slip Ring
Brush
R Load
+
Volts 0
-
0°
90°
180°
270°
360°

[Loop Shown in
Maximum Voltage Position]

Generator Construction

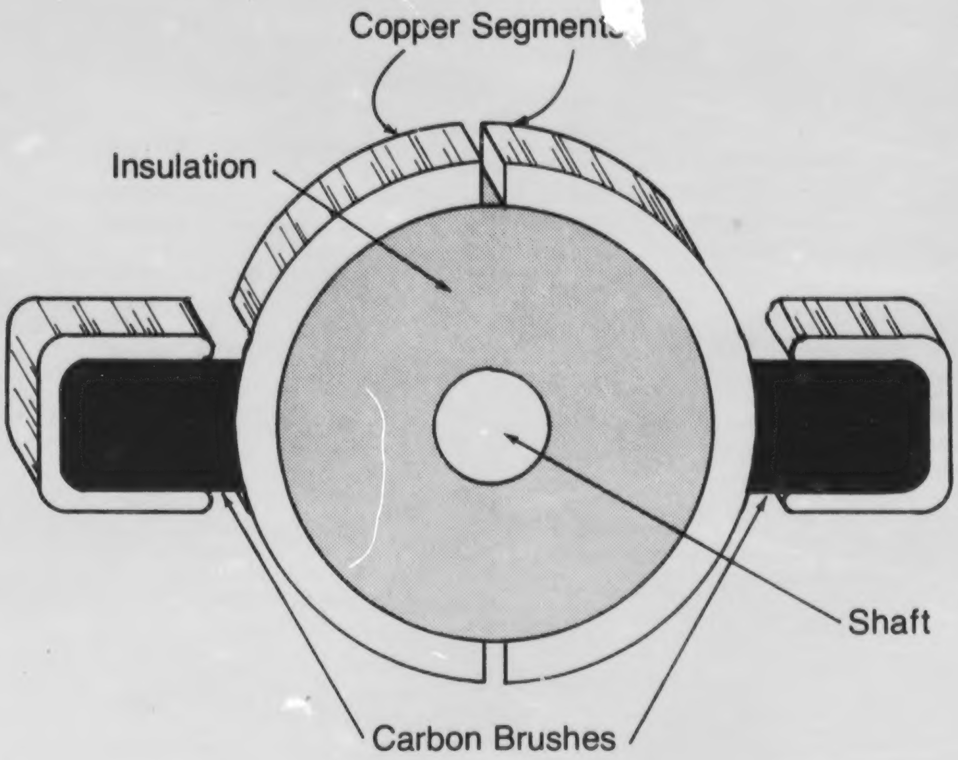

Two Pole Generator
Yoke
Pole Piece
Field Coil
N
S
Base
RL
Four Pole Generator
Yoke
Pole Piece
Field Coil
S
N
N
S
Base
RL
Generator Load

YOKE ASSEMBLY

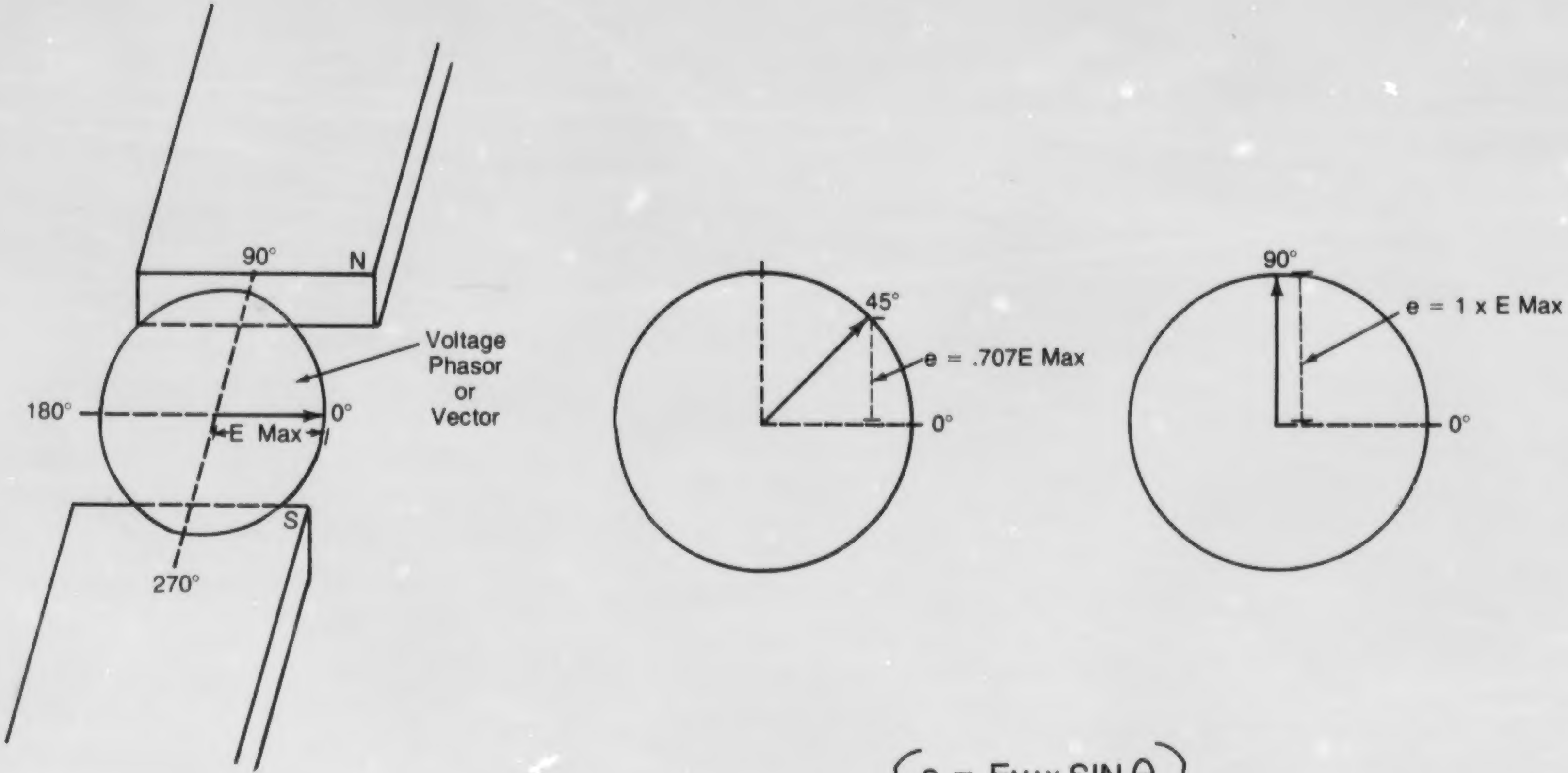

Carbon Brush
CORE
Armature Windings
Field Excitation Source
Insulation
Slip Ring

ARMATURE ASSEMBLY

DC Generator Commutator

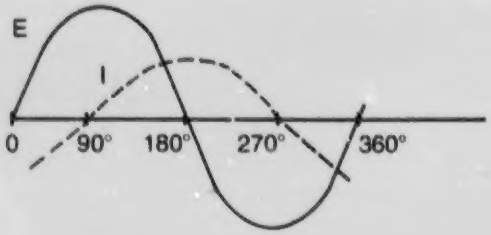

Copper Segments
Insulation
Shaft
Carbon Brushes

Voltage Phasor (Vector)

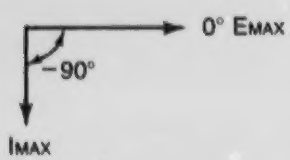

90°
N
Voltage Phasor or Vector
180°
0°
E Max
S
270°
45°
e = .707E Max
0°
90°
e = 1 x E Max
0°

$$\left\{\begin{aligned} e &= E_{MAX} \sin \theta \\ i &= I_{MAX} \sin \theta \end{aligned}\right\}$$

Comparison Sinusoidal and Phasor (Vector) Diagrams

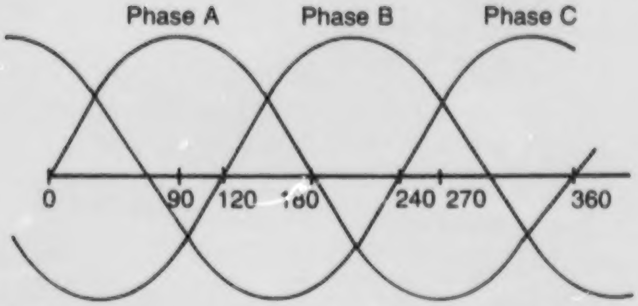

E
I
0
90°
180°
270°
360°

SINUSOIDAL GRAPH

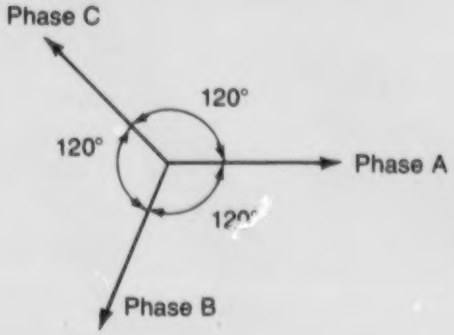

0° EMAX
−90°
IMAX

PHASOR DIAGRAM
(VECTOR DIAGRAM)

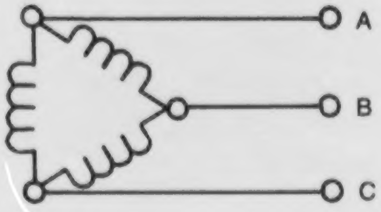
Three-Phase Power Generation



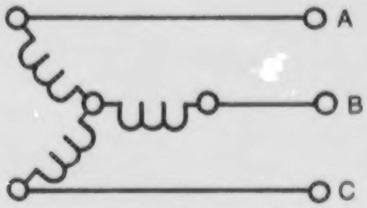
SINUSODIAL DIAGRAM


Phase C
120°
120°
Phase A
120°
Phase B

PHASOR (VECTOR) DIAGRAM



DELTA (Δ) CONNECTIONS



WYE (Y) CONNECTIONS

AC GENERATION
UNIT II

ASSIGNMENT SHEET #1--DETERMINE CURRENT FLOW DIRECTION

1. Mark these statements True (T) or False (F).

_____a. Moving a conductor which cuts the lines of a magnetic field induces a voltage in the conductor

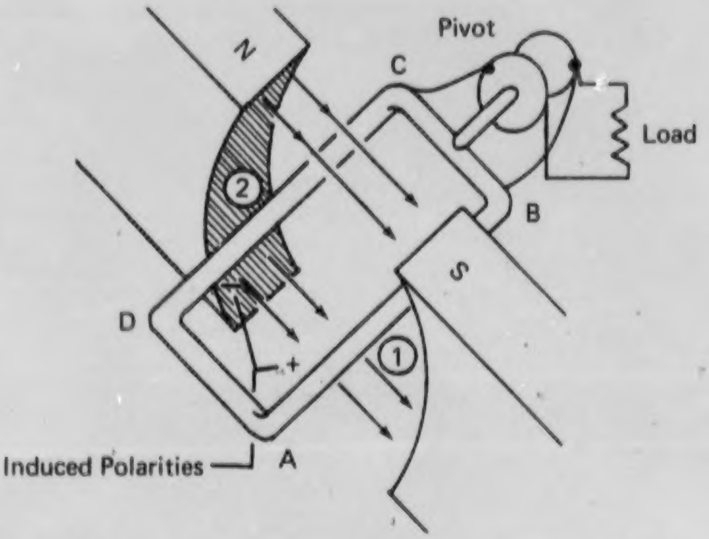
_____b. EMF is generated when the magnetic field is moved and the conductor is stationary (assuming that lines of flux are being cut)

_____c. The left-hand generator rule can be used to determine electron displacement

2. Match the following concerning the left hand generator rule.

_____a. Thumb	1. Direction of current flow
_____b. Forefinger	2. Direction of conductor motion
_____c. Middle finger	3. Direction of magnetic flux lines

3. Study the illustration and answer the following questions:



a. When leg (1) is moving downward, from which letter position will current move out of the loop into the circuit? (A or B)__________

b. When leg (1) moves downward, current will flow from (A or B)_____to (A or B)_____in leg (1)

ASSIGNMENT SHEET #1

c. When leg (2) moves upward, current will flow from (C or D)_____ to_____ (C or D) in leg (2)

d. When leg (2) gets to the shown position of leg (1), what happens to the current?____

AC GENERATION
UNIT II

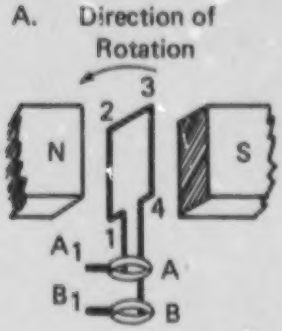
ASSIGNMENT SHEET #2--COMPUTE AC CYCLE INSTANTANEOUS VALUES

1. In the alternating current cycle the maximum EMF is generated when the conductor is moving

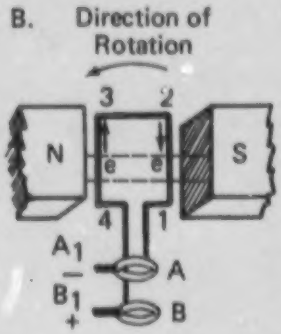
______a. Parallel with the lines of flux

______b. Perpendicular to the lines of flux

A.


Direction of Rotation
3
2
N
S
4
1
A1
A
B1
B

B.


Direction of Rotation
3
2
N
e
e
S
4
1
A1
–
A
B1
+
B

Cycle of the Generator

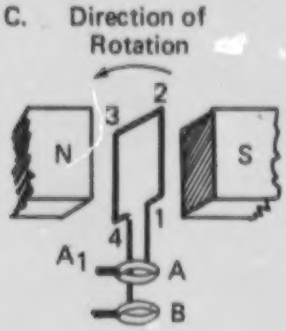
A. Start

B. Quarter Turn (90°)

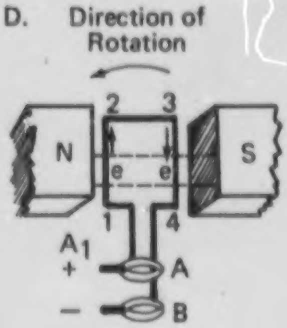
C. Half Turn (180°)

D. Three-Quarter Turn (270°)

C.


Direction of Rotation
2
3
N
S
1
4
A1
A
B

D.


Direction of Rotation
2
3
N
e
e
S
1
4
A1
+
A
–
B

2. In the illustration above, the two cycle positions (A, B, C, or D) where the maximum voltage is induced in the conductor are______________________and____________

3. The minimum voltage induced is zero volts and occurs at cycle positions___________ and____________________(see illustration)

4. In the illustration above, the maximum induced voltage occurs at degree positions __________and__________and zero voltage is induced at degree positions______ and__________

ASSIGNMENT SHEET #2

5. Using the formula $e = E_{max} \sin \theta$ and assuming a maximum induced voltage of 10 volts, compute the instantaneous voltage at

a. 30° = _____
b. 45° = _____
c. 90° = _____
d. 150° = _____
e. 300° = _____
f. 330° = _____

AC GENERATION
UNIT II

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

1. a. T
   b. T
   c. T
2. a. 2
   b. 3
   c. 1
3. a. B
   b. B to A
   c. D to C
   d. The current reverses direction

Assignment Sheet #2

1. b
2. B and D
3. A and C
4. 90 and 270; 0 and 180
5. a. 5
   b. 7.07
   c. 10
   d. 5
   e. -8.66
   f. -5

AC GENERATION
UNIT II

JOB SHEET #1--CONSTRUCT A SIMPLE GENERATOR

I. Tools and materials

   A. Horseshoe magnet

   B. Galvanometer or microammeter (optional-oscilloscope, see step F)

   C. 12 feet hookup wire

II. Procedure

   A. Make a coil of the wire small enough to easily pass into and out of the horseshoe magnet but leaving enough ends to connect to the galvanometer or microammeter

   B. Connect the ends of the coiled wire to the meter

   C. Observe the meter while rapidly moving the wire into the magnet

   (NOTE: The meter needle should deflect.)

   D. Observe the meter while rapidly moving the wire out of the magnet

   (NOTE: The meter needle should deflect in the opposite direction than in step C.)

   E. Repeat steps C and D but leave the coiled wire stationary and move the magnet rapidly past the coil

   F. If you are using an oscilloscope in your lab, repeat steps C, D, and E but with the ends of the wire connected to the input vertical voltage terminals of your oscilloscope

   G. Observe the indications on the scope

AC GENERATION
UNIT II

JOB SHEET #2--IDENTIFY GENERATOR COMPONENTS

(NOTE: The instructor may use this job sheet as a demonstration.)

I. Tools and materials

   A. Automobile alternator

   B. Automobile DC generator (Optional)

II. Procedure

   A. Identify the pulley location, the cooling fan, the front and rear bearings, the brush location, and other parts visible before alternator disassembly

   B. Disassemble the alternator carefully and observe the location (and condition) of the brushes, the brush springs, brush holder, front and rear bearings, rotor, and stator

   C. Observe the method of winding in both stator and rotor

   (NOTE: In most alternators the magnetic field is in the rotor and the output alternating current is taken from the stator windings.)

   D. Observe the connections to the brushes and to the stator windings

   E. Repeat steps A through D as appropriate using an automobile DC generator, if one is available

AC GENERATION
UNIT II

NAME______________________

TEST

1. Match the terms on the right with their correct definitions.

_____a. Rotating member of an electrical machine that has a shaft

_____b. A combination of circuits producing output voltages differing in phase by one-third cycle (120°)

_____c. Current that reverses periodically and that has alternating positive and negative values

_____d. A winding on an electrical machine which produces an electromagnetic field

_____e. The difference in phase between two sinusoidal functions having the same periods

_____f. A complex number having magnitude and direction

_____g. A carbon conductor connecting the stationary and moving parts of an electrical machine

_____h. The stationary portion of an electrical machine

_____i. Metal current-carrying members that are insulated from one another by insulating segments and that make contact with brushes

_____j. Process of generating voltage in a conductor by means of a magnetic field

_____k. Electrical coupling by a magnetic field

_____l. The measure of the progression of a periodic wave in time from a chosen reference

_____m. Metal rings that conduct current into and out of the rotor of an electrical machine

1. Electromagnetic induction
2. Induced voltage
3. Rotor
4. Stator
5. Generator
6. Alternating current
7. Phasor
8. Phase angle
9. Phase difference
10. Field winding
11. Slip rings
12. Brushes
13. Three-phase circuit
14. Induction
15. Commutator

_____n. Voltage produced in a conductor by a change in magnetic flux

_____o. Machine which converts mechanical power to electrical power

2. Select true statements concerning electromagnetic induction by placing an "X" in the appropriate blanks.

   _____a. Conductor moved through a magnetic field produces voltage in the conductor

   _____b. A magnetic field moved across a conductor produces voltage in the conductor

   _____c. Phenomenon is called electromagnetic induction

3. Select requirements for generating voltage electromagnetically by placing an "X" in the appropriate blanks.

   _____a. Magnetic field

   _____b. Stator

   _____c. Rotor

   _____d. Commutator

   _____e. Conductor in the magnetic field

   _____f. Brushes

   _____g. Relative motion between conductor and magnetic field

   _____h. Slip rings

4. Discuss the left hand generator rule.

   a. Direction of current induced in a conductor depends upon:

      1)____

      2)____

   b. In the left hand method of determining electron flow direction:

      1)____

      2)____

      3)____

5. Select true statements concerning the magnitude of generated voltage by placing an "X" in the appropriate blanks.

   ______ a. The magnitude of induced voltage is proportional to number of flux lines cut per second by conductor

   ______ b. Number of flux lines cut per second by conductor is determined by velocity of conductor

   ______ c. Number of flux lines cut per second by conductor is determined by length of conductor

   ______ d. Number of flux lines cut per second by conductor is determined by magnetic field strength

   ______ e. Number of flux lines cut per second by conductor is not related to angle that conductor cuts field

6. Select true statements concerning elementary cycle generation by placing an "X" in the appropriate blanks.

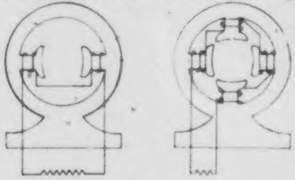
   ______ a. Start with no lines being cut to maximum cutting of lines by rotating coil 1/4 turn, from no induced voltage to maximum induced voltage

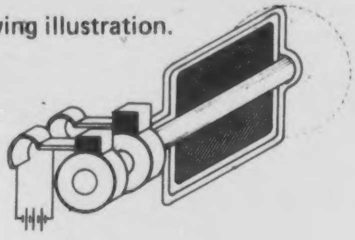
   ______ b. Second 1/4 turn changes conductor from position of cutting maximum lines to movement parallel to lines, from maximum voltage to zero

   ______ c. Third 1/4 turn changes conductor from position of no lines being cut to maximum cutting lines but in opposite direction from the first 1/4 turn, from zero voltage to maximum negative voltage

   ______ d. Fourth 1/4 turn changes conductor from maximum cutting of line to minimum, from maximum negative voltage back to zero; this completes one cycle of AC generated voltage

7. Discuss generator construction using the following illustration.





   a. Yoke and base

   b. Armature and slip rings

8. State two rules concerning DC generator construction.

a. ______________________________

b. ______________________________

9. Select true statements concerning voltage phasors or vectors by placing an "X" in the appropriate blanks.

_____a. Length of phasor equals maximum voltage or current generated

_____b. Phasor rotates clockwise through full 2 pi radians (360°) of the circle

_____c. Distance from end of phasor to horizontal base line at a given time equals the value of voltage or current at that time

_____d. Phasor solution is graphical equivalent of formulas $e = E_{max} \sin \theta$ or $i = I_{max} \sin \theta$

10. Select true statements concerning phase angle diagrams by placing an "X" in the appropriate blanks.

_____a. Comparison of two or more sinusoidal functions with same periods

_____b. Length of phasor arrow represents values of current or voltage

_____c. One phasor is drawn at 90 degree position as the reference

_____d. Other phasor(s) drawn relative in time (or rotational position) to the phasor chosen as reference

_____e. Phasor diagrams are equivalent to sinusoidal waveforms

11. Discuss elements of three-phase power generation

a. ______________________________

b. ______________________________

1) ______________________________

2) ______________________________

12. Determine current flow direction.

13. Compute AC cycle instantaneous values.

14. Demonstrate the ability to:

a. Construct a simple generator.

b. Identify generator components.

(NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

AC GENERATION
UNIT II

ANSWERS TO TEST

1.

a.	3	e.	9	i.	15	m.	11
b.	13	f.	7	j.	1	n.	2
c.	6	g.	12	k.	14	o.	5
d.	10	h.	4	l.	8		

2. a, b, c

3. a, e, g

4. Discussion should include:

   a. 1) Direction of motion
      2) Direction of magnetic flux

   b. 1) Point forefinger in direction of magnetic flux
      2) Point thumb in direction of conductor motion
      3) Middle finger points in direction of current flow in conductor

5. a, b, c, d

6. a, b, c, d

7. Discussion should include:

   a. Yoke and base
      1) Pole pieces project from yoke
      2) Field coils wound on pole pieces
      3) End bells which support
         a) Brush supports
         b) Shaft bearings

   b. Armature and slip rings
      1) Consists of many turns of insulated copper wire around a core and shaft
      2) Armature core mounted on shaft which rotates at high speeds
      3) Slip rings connect to ends of core winding
      4) Carbon brushes connect slip rings to external load
      5) Carbon is used because
         a) Relatively constant contact resistant
         b) Softness prevents excessive wear

8. a. Same as AC generator except slip rings are replaced with a commutator
   b. Commutator action produces a pulsating DC in output circuit

9. a, c, d

10. a, b, d, e

11. Discussion should include:
    a. Three generator windings equally spaced produces output voltages 120 degrees out of phase with each other (360°/3)
    b. Different connections possible are
        1) Delta
        2) Wye or star
12. Evaluated to the satisfaction of the instructor.
13. Evaluated to the satisfaction of the instructor.
14. Performance skills evaluated to the satisfaction of the instructor.

INDUCTANCE
UNIT III

UNIT OBJECTIVE

After completion of this unit, the student should be able to state Lenz's law, the formula for a henry, and formulas for mutual inductance. The student should also be able to identify kinds of inductors and determine transformer ratios. This knowledge will be evidenced by correctly performing the procedures outlined in the assignment and job sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms associated with inductance with their correct definitions.
2. Match inductance unit abbreviations with their correct definitions.
3. Discuss factors contributing to self-inductance.
4. Select true statements concerning Lenz's law.
5. State the formula for a henry.
6. List three factors that affect the amount of inductance of a coil.
7. Identify kinds of inductors.
8. State the formulas for total inductance of inductors connected in series and inductors connected in parallel.
9. List two factors that determine mutual inductance.
10. State formulas for mutual inductance, mutual inductance aiding, and mutual inductance opposing.
11. Select true statements about transformer ratios.
12. Demonstrate the ability to determine transformer ratios.

INDUCTANCE
UNIT III

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information, assignment, and job sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information and assignment sheets.

VI. Demonstrate and discuss the procedures outlined in the job sheet.

VII. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

- A. Objective sheet
- B. Information sheet
- C. Transparency masters
  1. TM 1--Induction
  2. TM 2--Self-Inductance in a Coil
  3. TM 3--Coils of Various Inductances
  4. TM 4--Coefficient of Coupling
  5. TM 5--Transformer Ratios
- D. Assignment sheets
  1. Assignment Sheet #1--Answer Questions Regarding Induction and Inductors
  2. Assignment Sheet #2--Solve for L_T
  3. Assignment Sheet #3--Answer Questions Concerning Mutual Inductance
  4. Assignment Sheet #4--Solve Problems Concerning Transformer Ratios

E. Answers to assignment sheets

F. Job Sheet #1--Determine Transformer Ratios

G. Test

H. Answers to test

II. References:

A. Bernard Grob, *Basic Electronics.* New York: McGraw-Hill, 1977.

B. *IEEE Standard Dictionary of Electrical and Electronic Terms.* New York: John Wiley and Sons, 1972.

INDUCTANCE
UNIT III

INFORMATION SHEET

I. Terms and definitions

A. Inductor--A device that introduces inductance into an electrical circuit (usually a coil)

B. Inductance--The property of an electric circuit when a varying current induces an EMF in that circuit or another circuit

C. Self-inductance--The property of an electric circuit when an EMF is induced in that circuit by a change of current

D. Henry--The unit of inductance

E. Permeability--The measure of the ease with which material will pass lines of flux

F. Mutual inductance--The property of two circuits whereby an EMF is induced in one circuit by a change of current in the other

G. Coupling coefficient--A number indicating the fraction of flux lines of one circuit cutting another circuit

H. Transformer--A device that transfers changing current and voltage from one circuit to another by inductive coupling

II. Inductance unit abbreviations and definitions

A. Inductance--L

B. Henry--h

C. Rate of current change--di/dt

D. Mutual inductance--L_M (or M)

E. Coefficient of coupling--k

F. Counterelectromotive force--CEMF

G. Permeability--μ

III. Factors contributing to self-inductance

A. Inductance is present because a changing current always produces a changing magnetic field (Transparency 1)

B. Changing magnetic field cuts conductors causing a generator action

C. Induced current by changing magnetic field opposes the originating current (Transparency 2)

INFORMATION SHEET

IV. Lenz's law

A. Induced voltage at every instant opposes any change in circuit current

B. Induced voltage is called counter electromotive force (CEMF)

C. Induced voltage is so important that it has the status of a physical law called Lenz's law

D. The current in a conductor, as a result of an induced voltage, is such that the change in magnetic flux due to it is opposite to the change in flux that caused the induced voltage

V. The formula for a henry--$L = \frac{CEMF}{di/dt}$

(NOTE: One henry of inductance is present when one ampere change per second causes a CEMF of one volt. The henry is a relatively large unit; most inductors are measured in millihenries (mh) or microhenries (μh).)

VI. Factors affecting inductance of coils

A. Number of turns--Inductance varies directly with the square of the number of turns

B. Permeability of core--Inductance varies directly with the permeability of the core

C. Cross-sectional area of core--Inductance varies directly with the cross-sectional area of the core

D. Length of core--Inductance varies inversely with the length of the core

VII. Kinds of inductors (Transparency 3)

A. Air core

B. Iron core

(NOTE: Core materials can include ferrite, powdered iron, laminated iron and other materials.)

VIII. Inductors in circuits

A. Inductors in series

1. $L_T = L_1 + L_2 + ...$

(NOTE: This is additive, similar to resistors in series)

2. Series formula assumes no magnetic coupling between inductors

INFORMATION SHEET

B. Inductors in parallel

1. Reciprocal formula:

$$L_T = \frac{1}{1/L_1 + 1/L_2 + 1/L_3 + \ldots}$$

2. Unequal branch formula:

$$L_T = \frac{L_1 \times L_2}{L_1 + L_2}$$

3. Formulas assume no magnetic coupling between inductors

4. Total inductance is less than smallest parallel branch

IX. Factors determining mutual inductance

A. Coefficient of coupling between inductors (Transparency 4)

B. Inductance of each inductor

X. Formulas for mutual inductance

A. Formula for mutual inductance--$L_M = k\sqrt{L_1 \times L_2}$

B. Mutual inductance aiding--Total inductance, $L_T = L_1 + L_2 + 2L_M$

C. Mutual inductance opposing--Total inductance, $L_T = L_1 + L_2 - 2L_M$

XI. Transformer ratios (Transparency 5)

A. Turns ratio is the ratio of number of turns in secondary winding to number of turns in primary winding (T_s/T_p)

1. Step up transformer--When T_s is larger than T_p

2. Step down transformer--When T_s is smaller than T_p

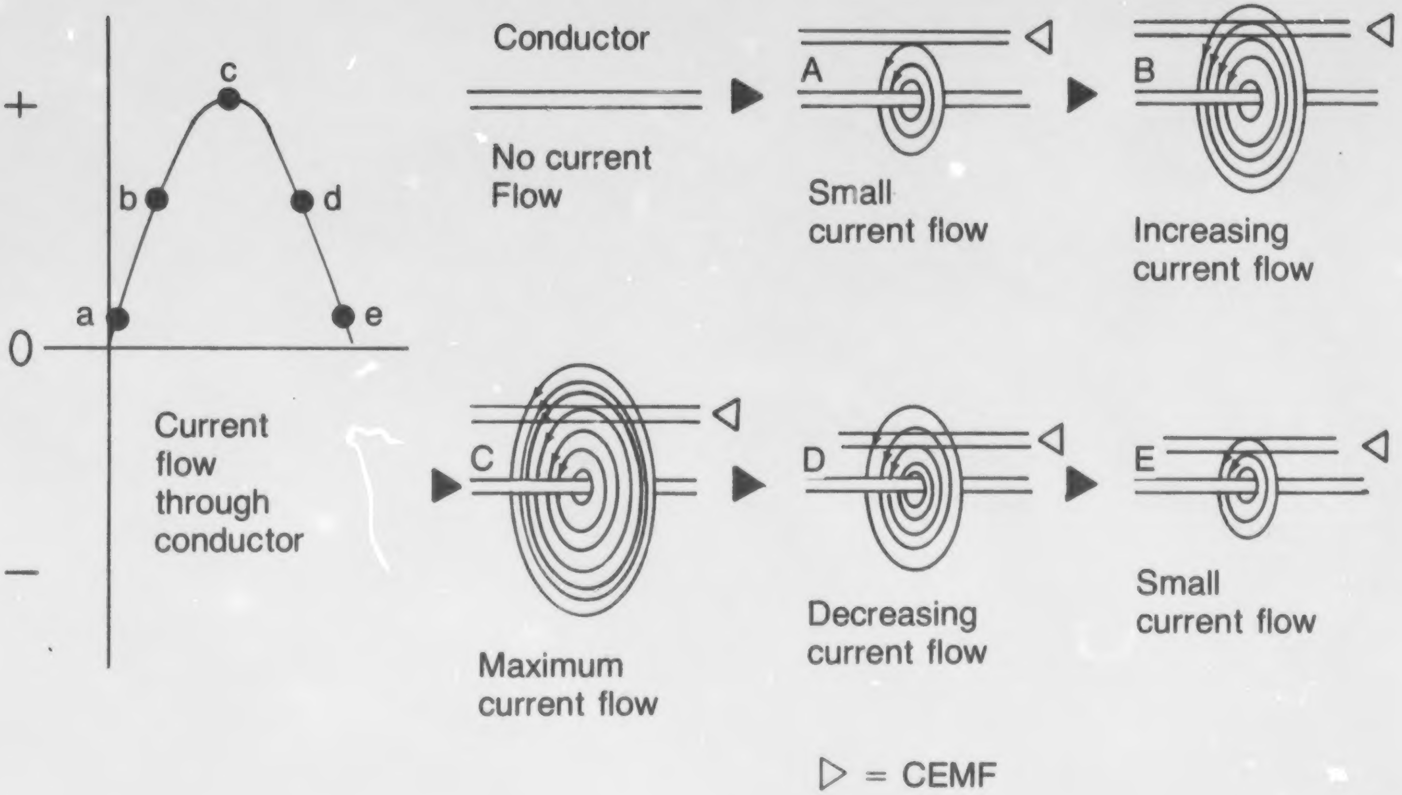
B. Voltage ratio, E_s/E_p, equals turns ratio with unity coupling

C. Current ratio, I_s/I_p, equals inverse of voltage or turns ratio; that

is, $T_s/T_p = E_s/E_p = I_p/I_s$

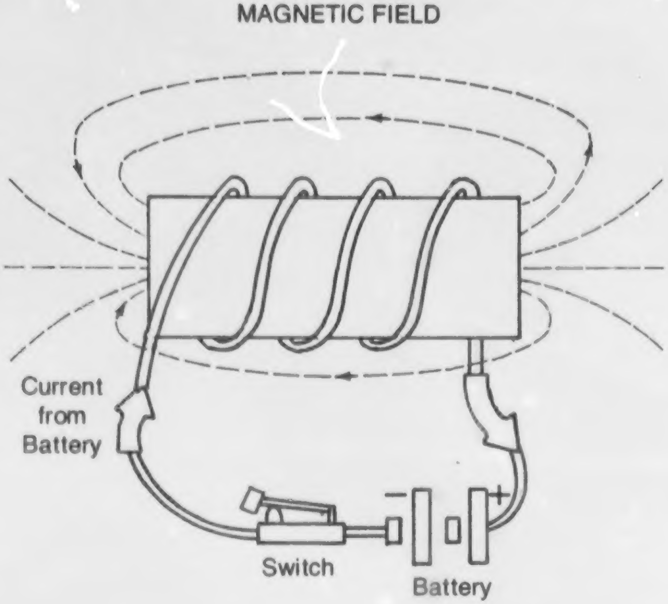
D. Power ratio, Po/Pi; power out is less than power in

Induction

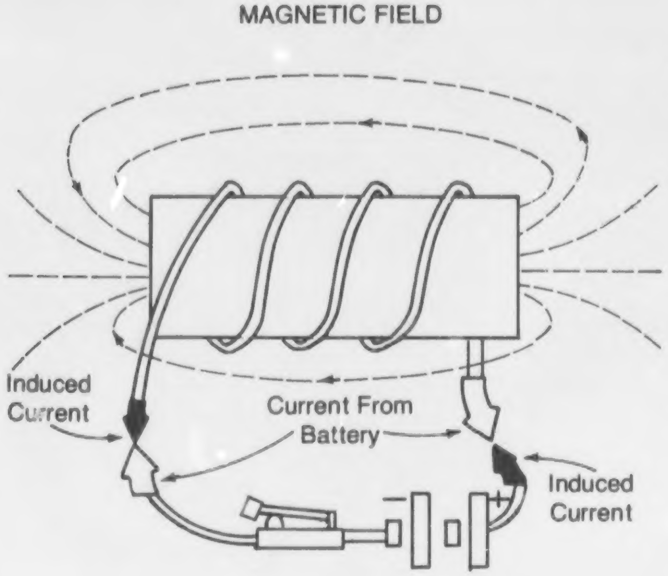

+
0
−
a
b
c
d
e
Current flow through conductor
Conductor
No current Flow
A
Small current flow
B
Increasing current flow
C
Maximum current flow
D
Decreasing current flow
E
Small current flow
▷ = CEMF

Relationship of magnetic field around a wire to current flowing through the wire.

Self-Inductance in a Coil


MAGNETIC FIELD
Current from Battery
Switch
−
+
Battery

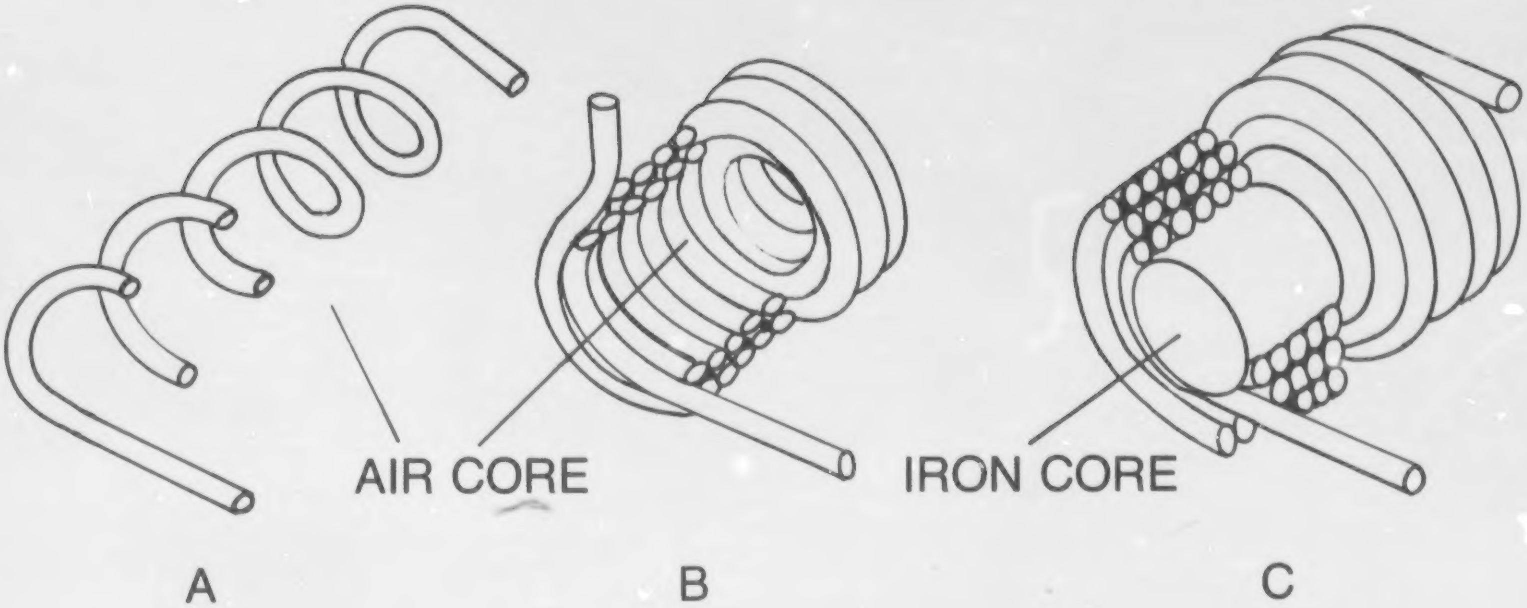
A. Current Creates Magnetic Field


MAGNETIC FIELD
Induced Current
Current From Battery
−
+
Induced Current

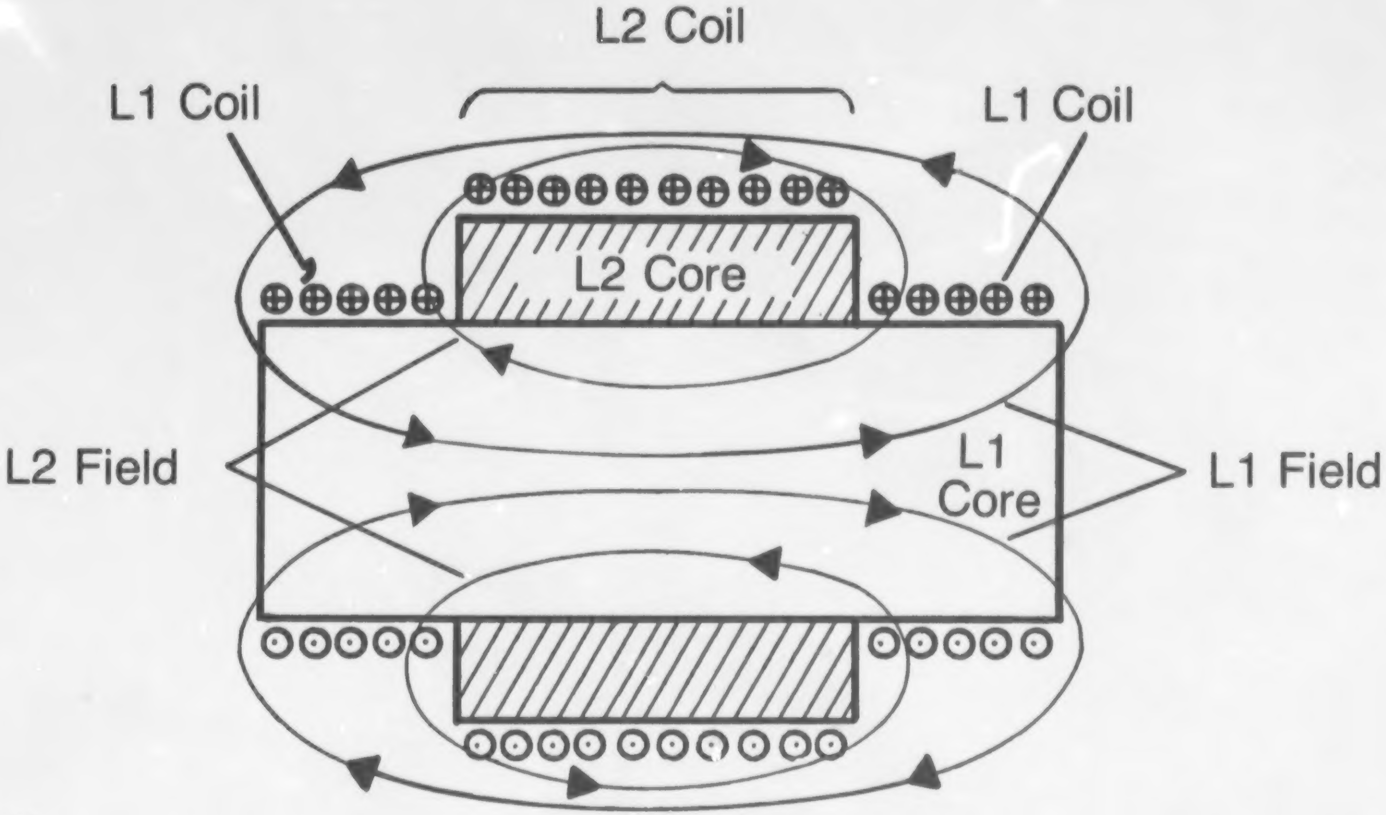
B. Magnetic Field Induces Opposing Current

Coils of Various Inductances

(NOTE: Inductances use many different materials in the cores.)


AIR CORE
IRON CORE
A
B
C

Coefficient of Coupling


L2 Coil
L1 Coil
L1 Coil
L2 Core
L2 Field
L1 Core
L1 Field

647

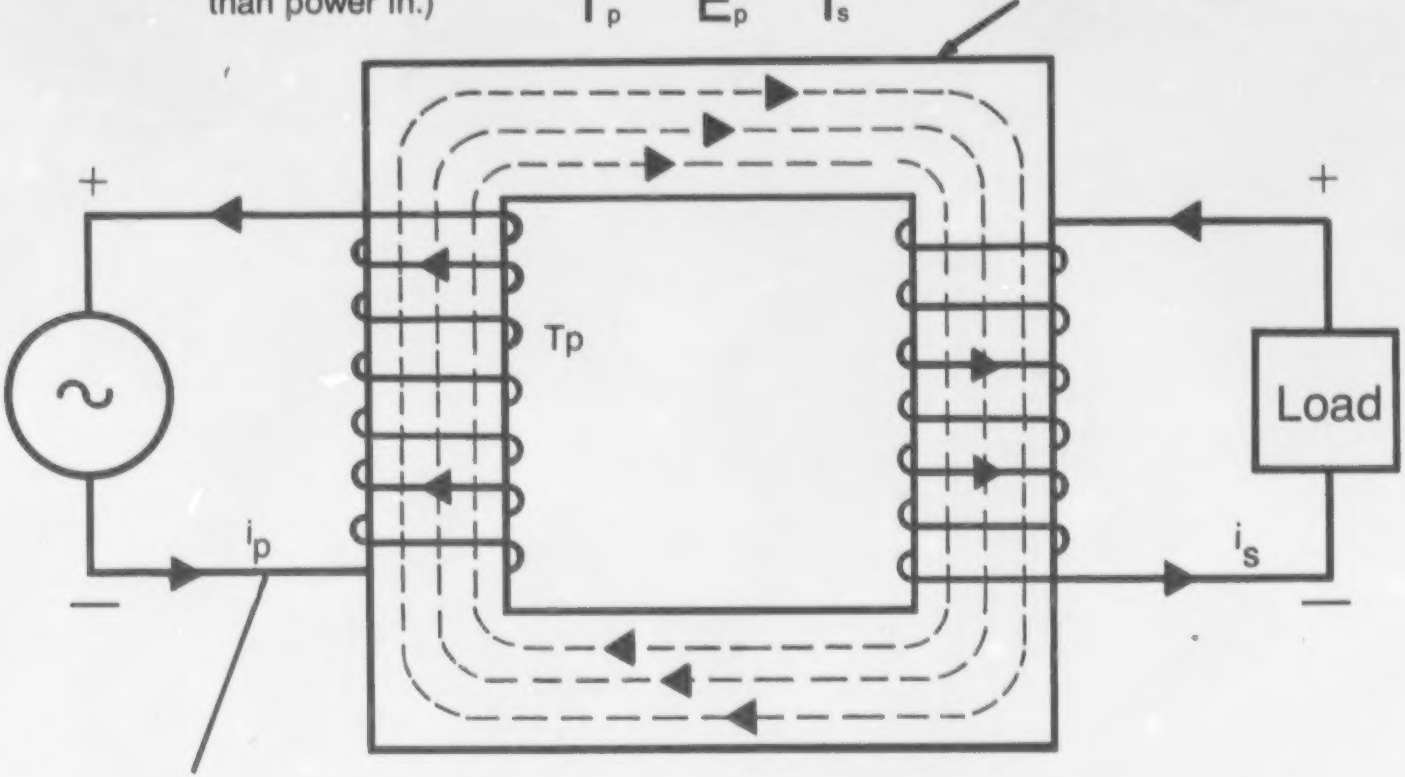
648

Transformer Ratios

$$\frac{T_s}{T_p} = \frac{E_s}{E_p} = \frac{I_p}{I_s}$$

(NOTE: Power out is less than power in.)

Flux Field



Instantaneous Current Flow

INDUCTANCE
UNIT III

ASSIGNMENT SHEET #1--ANSWER QUESTIONS REGARDING INDUCTION AND INDUCTORS

1. Match the statement on the right with their effects.

_____a. Source current increased	1. Inductance and induced EMF source current
_____b. Source current decreased	2. Inductance and induced EMF sustain source current

2. Match the phrases on the right with their effects.

(NOTE: Answers may be used more than once.)

_____a. Decrease core permeability	1. Inductance increases
_____b. Add turns to a coil	2. Inductance decreases
_____c. Increase cross-sectional area of core	
_____d. Decrease length of core	

3. Place an "X" next to statements which correctly finish this phrase: In an inductive circuit when the switch is suddenly opened,

_____a. the magnetic field around the coil begins to collapse

_____b. current tries to continue to flow due to induced voltage

_____c. current decays rather than abruptly going to zero

_____d. all of the above are correct

4. What is another name for induced voltage?

5. True or false:

_____a. The induced voltage caused by inductance opposes any change in circuit current

_____b. The induced voltage is called CEMF

6. Name three different core materials used in inductor construction.

a. ______________________________

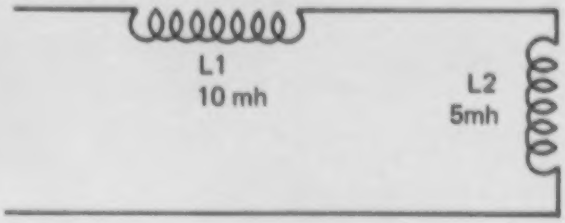
b. ______________________________

c. ______________________________

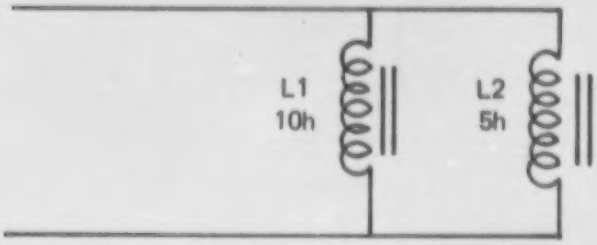
INDUCTANCE
UNIT III

ASSIGNMENT SHEET #2--SOLVE FOR L_T

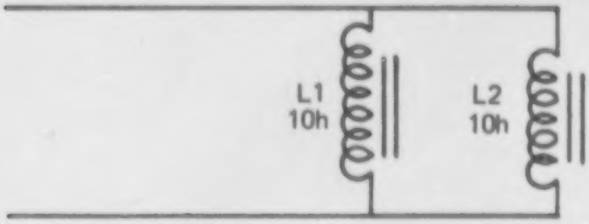
1. Find L_T in this circuit (assume no mutual inductance).


L1
10 mh
L2
5mh

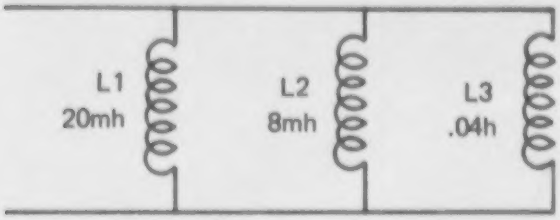
2. Solve for L_T.



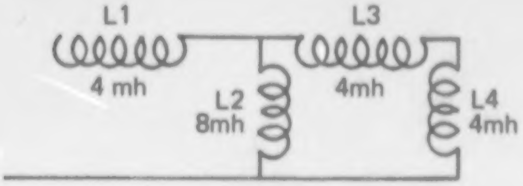
3. Solve for L_T.


L1
10h
L2
10h

4. Solve for L_T.


L1
20mh
L2
8mh
L3
.04h

5. Solve for L_T.


L1
4 mh
L2
8mh
L3
4mh
L4
4mh

ASSIGNMENT SHEET #2

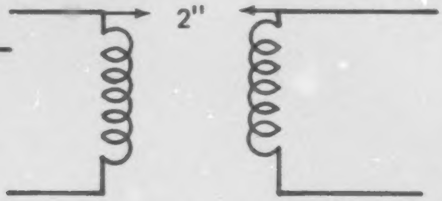
6. $L = \frac{CEMF}{di/dt}$ If CEMF equals 100 volts when a change in current of 5000 amperes per second occurs, how much inductance is present?________

INDUCTANCE
UNIT III

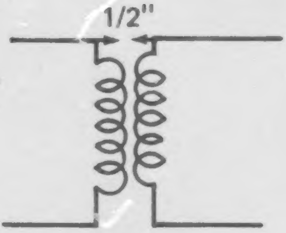
ASSIGNMENT SHEET #3--ANSWER QUESTIONS CONCERNING MUTUAL INDUCTANCE

1. Which pair of coils has the greatest mutual inductance? (Assume all except the spacing to be identical.)

a. _____



b. _____



2. In problem one, is the coil with the greatest coefficient of coupling (A) or (B)?

3. The coefficient of coupling between two coils is found to be 0.2. If the coils both have 4 mh of inductance, the mutual inductance is________________________

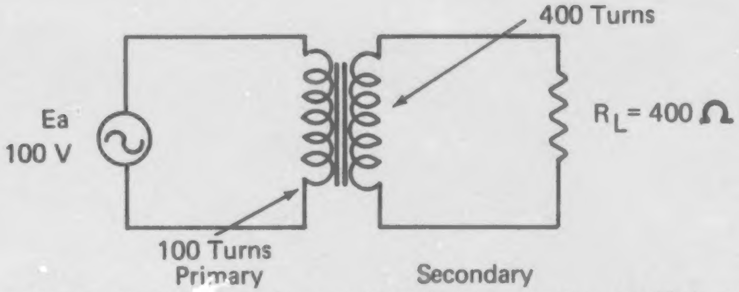
(HINT: $L_M = k \sqrt{L_1 \times L_2}$)

   a. If the coils are connected in series and the inductance is aiding, the total inductance is________________________

   b. If the coils are connected in series and the inductance is opposing, the total inductance is________________________

INDUCTANCE
UNIT III

ASSIGNMENT SHEET #4--SOLVE PROBLEMS CONCERNING TRANSFORMER RATIOS


400 Turns
Ea
100 V
$R_L = 400\ \Omega$
100 Turns
Primary
Secondary

The above schematic is a perfect transformer (that is, the coupling coefficient is 1). The primary has 100 turns and the secondary has 400 turns. A 400-ohm load is across the secondary.

Find:

1. Secondary voltage, E_s = ____________________
2. Secondary current, I_s = ____________________
3. Primary current, I_p = ____________________
4. Power in the secondary circuit, P_s = __________
5. Power in the primary circuit, P_p = __________
6. This transformer is a (step-up) (step-down) transformer.

INDUCTION
UNIT III

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

1. a. 1
   b. 2

2. a. 2
   b. 1
   c. 1
   d. 1

3. d.

4. Counter electromotive force (CEMF)

5. a. True b. True

6. Air, iron, ferrite, powered iron (any three)

Assignment Sheet #2

1. 15 mh
2. 3.33 mh
3. 5 h
4. 5 mh
5. 8 mh
6. 20 mh

Assignment Sheet #3

1. b

2. B

3. a. .8mh
   b. 9.6mh
   c. 6.4mh

Assignment Sheet #4

1. 400 V
2. 1 A
3. 4 A
4. 400 W
5. 400 W
6. Step-up

INDUCTANCE
UNIT III

JOB SHEET #1--DETERMINE TRANSFORMER RATIOS

I. Tools and materials

A. Filament transformer (approximately 110v to 6v)

B. Autotransformer or signal generator

C. 30-ohm, 5W resistor

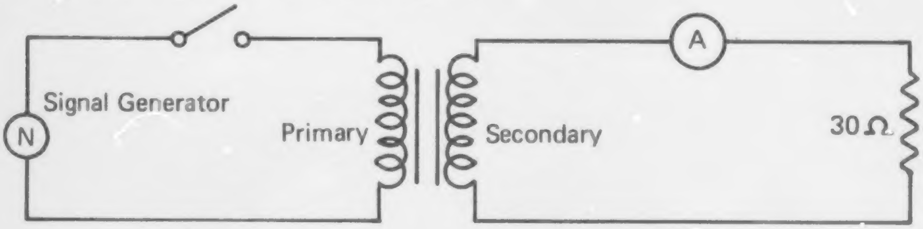
D. Multimeters

E. Electrical wire to build circuit

II. Procedure

A. Connect the following circuit (Figure 1)

FIGURE 1



B. Adjust the signal input to 100 volts

C. Close the switch and record the secondary current, I_s

D. Measure and record the primary voltage, E_p

E. Measure and record the secondary voltage, E_s

F. Measure and record the load resistor (approximately 30 ohms)

G. Compare the measured secondary current, I_s, with that obtained using Ohms' law (E_s/R_L). Explain differences.

H. Measure and record I_p

I. Use the voltage ratio and I_p to compute I_s, then compare with I_s

values obtained in Steps C and G

J. Calculate the turns ratio of the transformer

K. Remove the load resistor and leave the secondary open

JOB SHEET #1

L. Measure and record the primary current, I_p, with an open secondary

M. Compare your voltage ratio with that indicated by the transformer manufacturer

INDUCTANCE
UNIT III

NAME ______________________________

TEST

1. Match the terms on the right with their correct definitions.

______a. The property of an electric circuit when an EMF is induced in that circuit by a change of current

______b. The property of two circuits whereby an EMF is induced in one circuit by a change of current in the other

______c. A device that transfers changing current and voltage from one circuit to another by inductive coupling

______d. A device that introduces inductance into an electrical circuit

______e. The unit of inductance

______f. The measure of the ease with which material will pass lines of flux

______g. The property of an electric circuit when a varying current induces an EMF in that circuit or another circuit

______h. A number indicating the fraction of flux lines of one circuit cutting another circuit

1. Inductor
2. Inductance
3. Self-inductance
4. Henry
5. Permeability
6. Mutual inductance
7. Coupling coefficient
8. Transformer

2. Match the inductance unit abbreviations on the right with their correct definitions.

______a. Inductance

______b. Henry

______c. Rate of current change

______d. Mutual inductance

______e. Coefficient of coupling

______f. Counterelectromotive force

______g. Permeability

1. L_M
2. CEMF
3. L
4. h
5. k
6. di/dt
7. μ

3. Discuss factors contributing to self-inductance.

4. Select true statements concerning Lenz's law by placing an "X" in the appropriate blanks.

_____a. Induced voltage at every instant opposes any change in circuit current

_____b. Induced voltage is called counter electromotive force (CEMF)

_____c. Induced voltage is called counter electromagnetic input (CEMI)

_____d. Induced voltage is so important that it is the basis of Ohm's law

_____e. The current in a conductor, as a result of an induced voltage, is such that the change in magnetic flux due to it is opposite to the change in flux that caused the induced voltage

5. State the formula for a henry.

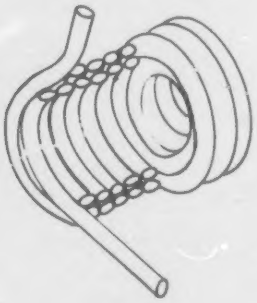
6. List three factors that affect the amount of inductance of a coil.

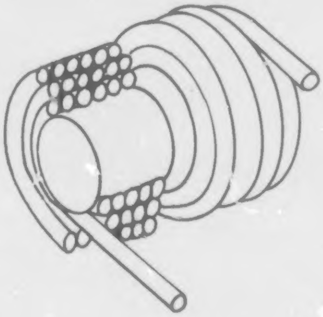
a. ____________________

b. ____________________

c. ____________________

7. Identify kinds of inductors.





a. ____________________ b. ____________________

8. State the formulas for total inductance of inductors connected in series and inductors connected in parallel.

   a. Inductors in series--

   b. Inductors in parallel

      a. Reciprocal formula--

      b. Unequal branch formula--

9. List two factors determining mutual inductance.

   a. ______________________________

   b. ______________________________

10. State formulas for:

    a. Mutual inductance--

    b. Mutual inductance aiding--

    c. Mutual inductance opposing--

11. Select true statements about transformer ratios by placing an "X" in the appropriate blanks.

    _____a. Turns ratio is the ratio of number of turns in secondary winding to number of turns in primary winding (T_s/T_p)

    _____b. In the step up transformer, T_s is larger than T_p

    _____c. In the step down transformer, T_p is smaller than T_s

    _____d. The voltage ratio, E_s/E_p equals turns ratio with unity coupling

    _____e. Current ratio, I_s/I_p, equals voltage or turns ratio

    _____f. Power ratio, P_o/P_r; power in is less than power out

12. Demonstrate the ability to determine transformer ratios.

    (NOTE: If this activity has not been accomplished prior to the test, ask your instructor when it should be completed.)

INDUCTANCE
UNIT III

ANSWERS TO TEST

1. a. 3
   b. 6
   c. 8
   d. 1
   e. 4
   f. 5
   g. 2
   h. 7

2. a. 3
   b. 4
   c. 6
   d. 1
   e. 5
   f. 2
   g. 7

3. Discussion should include:

   a. Inductance is present because a changing current always produces a changing magnetic field

   b. Changing magnetic field cuts conductors causing a generator action

   c. Induced current by changing magnetic field opposes the originating current

4. a, b, e

5. Formula--$L = \frac{CEMF}{di/dt}$

6. Any three of the following:

   a. Number of turns--Inductance varies directly with the square of the number of turns

   b. Permeability of core--Inductance varies directly with the permeability of the core

   c. Cross-sectional area of core--Inductance varies directly with the cross-sectional area of the core

   d. Length of core--Inductance varies inversely with the length of the core

7. a. Air core
   b. Iron core

8. a. Inductors in series--$L_T = L_1 + L_2 + \ldots$
   b. Inductors in parallel

      a) $L_T = \frac{1}{1/L_1 + 1/L_2 + 1/L_3 + \ldots}$

      b) $L_T = \frac{L_1 \times L_2}{L_1 + L_2}$

9. a. Coefficient of coupling between inductors
   b. Inductance of each inductor

10. a. Mutual inductance--$L_M = k \sqrt{L_1 \times L_2}$

    b. Mutual inductance aiding--

    Total inductance, $L_T = L_1 + L_2 + 2\,L_M$

    c. Mutual inductance opposing--

    Total inductance, $L_T = L_1 + L_2 - 2L_M$

11. a, b, d

12. Performance skills evaluated to the satisfaction of the instructor.

INDUCTIVE REACTANCE
UNIT IV

UNIT OBJECTIVE

After completion of this unit, the student should be able to state formulas for computing inductive reactance; true, apparent, and reactive power; power factor; and the Q of an inductor. The student should also be able to compute inductive reactance and the various values in RL circuits; demonstrate the ability to show the effect of inductance in AC circuits; and solve for values of an operating RL circuit. This knowledge will be evidenced by correctly performing the procedures outlined on the assignment and job sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms associated with inductive reactance with their correct definitions.
2. Match symbols concerning inductive reactance with their correct definitions.
3. List three factors needed to compute inductive reactance.
4. State the formula for computing inductive reactance.
5. Select true statements describing current and voltage relationships in RL circuits.
6. Compute the applied voltage and impedance in a series RL circuit.
7. State three formulas for determining true power.
8. State three formulas for determining apparent power.
9. State three formulas for determining reactive power.
10. State four formulas for determining power factor.
11. State the formula for determining quality factor (Q) or figure of merit of an inductor.
12. Select true statements concerning inductive time constants.
13. Complete the labels on a universal time constant chart.
14. Compute inductive reactance.
15. Compute applied voltage and impedance of RL circuits.

16. Compute power in reactive circuits.
17. Compute the Q of inductors.
18. Solve time constant problems.
19. Demonstrate the ability to:
    - a. Show the effect of inductance in AC circuits.
    - b. Solve for values of an operating RL circuit.

INDUCTIVE REACTANCE
UNIT IV

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information, assignment, and job sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information and assignment sheets.

VI. Demonstrate and discuss the procedures outlined in the job sheets.

VII. Set up an RL circuit and with a dual trace oscilloscope demonstrate the phase relationships present in the circuit.

VIII. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

- A. Objective sheet
- B. Information sheet
- C. Transparency masters
  - 1. TM 1--RL Circuit and Current Rise
  - 2. TM 2--Current and Voltage Relationships in RL Circuits
  - 3. TM 3--Universal Time Constant Chart
- D. Assignment sheets
  - 1. Assignment Sheet #1--Compute Inductive Reactance
  - 2. Assignment Sheet #2--Compute Applied Voltage and Impedance of RL Circuits
  - 3. Assignment Sheet #3--Compute Power in Reactive Circuits
  - 4. Assignment Sheet #4--Compute the Q of Inductors
  - 5. Assignment Sheet #5--Solve Time Constant Problems

E. Answers to assignment sheets

F. Job sheets

    1. Job Sheet #1--Show the Effect of Inductance in AC Circuits

    2. Job Sheet #2--Solve for Values of an Operating RL Circuit

G. Test

H. Answers to test

II. References:

A. Grob, Bernard. *Basic Electronics.* New York: McGraw-Hill, 1977.

B. Marcus, Abraham, and Samuel E. Gendler. *Basic Electronics.* Englewood Cliffs, NJ: Prentice-Hall, 1971.

C. Hughes, L.E.C., R.W.B. Stephens, and L.D. Brown. *Dictionary of Electronics.* Barnes and Noble, 1969.

INDUCTIVE REACTANCE
UNIT IV

INFORMATION SHEET

I. Terms and definitions

A. Resistance--Opposition to current resulting in energy dissipation

B. Reactance--Opposition to current caused by voltage or current changes not resulting in energy dissipation

(NOTE: This opposition is caused by inductive and capacitive effects.)

C. Impedance--Opposition to current including both resistance and reactance

(NOTE: Resistance, reactance, and impedance are measured in ohms.)

D. Inductive reactance--Circuit opposition caused by inductance

E. Power--The rate of energy consumption in a circuit (true power)

F. Reactive power--The product of reactive voltage and amperes (or the equivalent) in an AC circuit

G. Apparent power--The product of volts and amperes (or the equivalent) in an AC circuit

H. Power factor--The ratio of true power (watts) to apparent power (volts-amperes) in an AC circuit

I. Phase angle--The angle that the current leads or lags the voltage in an AC circuit

(NOTE: The phase angle is expressed in degrees or radians.)

J. Angular velocity--The rate of change of cyclical motion

(NOTE: Angular velocity is expressed in radians per second.)

K. Time constant--The time required for an exponential quantity to change by an amount equal to 0.632 times the total change that will occur

II. Symbols and definitions

A. X--Reactance in ohms

B. X_L--Inductive reactance in ohms

C. f--Frequency in hertz

D. R--Resistance in ohms

INFORMATION SHEET

E. ω --Angular velocity in radians per second

(NOTE: ω also equals $2\pi f$.)

F. Z--Impedance in ohms

G. 2π --Radians in one cycle

(NOTE: 2π equals approximately 6.28.)

H. VARS (Volt Amperes Reactive)--Reactive apparent power

I. PF--Power factor

III. Factors needed to compute inductive reactance, X_L

A. ω --Angular velocity in radians per second ($2\pi f$)

B. L--Inductance in henries

C. f--Frequency in hertz

IV. Formula for computing inductive reactance (sinusoidal waveforms)

$$X_L = \omega L = 2\pi fL$$

(NOTE: Inductive reactance is directly proportional to rate of change of current or voltage (frequency), and the amount of inductance.)

V. Current and voltage relationships in RL circuits

A. Current lags voltage by 90° in a pure inductive circuit

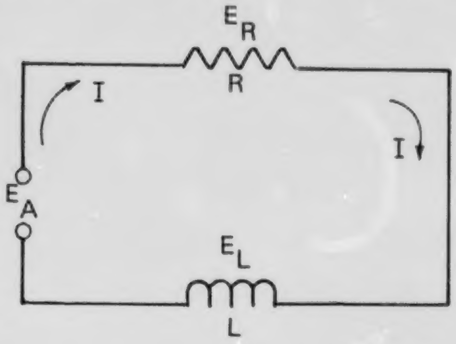
B. Current and voltage are in phase in a pure resistive circuit

C. In an RL circuit, current lags voltage between 0° and 90° depending upon:

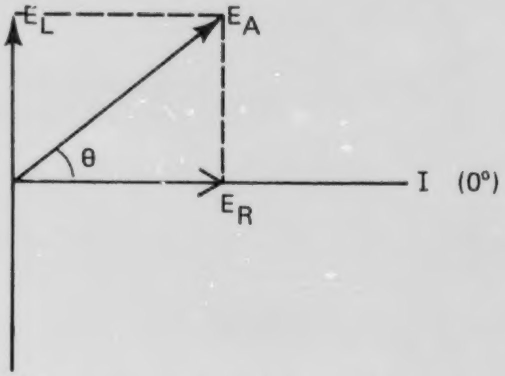
1. Relative amounts of R and L present
2. Frequency of applied voltage or current (angular velocity)

INFORMATION SHEET

VI. Computing applied voltage and impedance in series RL circuits



RL Circuit



RL Phase Relationships (RMS Values)

A. Current is same in R and in L

(NOTE: This is used as reference.)

B. Voltage across resistor (E_R) is in phase with current

C. Voltage across inductor (E_L) is 90° ahead of current

D. Applied voltage (E_A) is vector sum of the two out-of-phase voltages and equals

$$E_A = \sqrt{(E_R)^2 + (E_L)^2} \quad \text{(Hypotenuse of right triangle)}$$

E. Dividing each quantity by current results in impedance formula:

$$Z = \sqrt{(R)^2 + (X_L)^2}$$

F. Phase angle is the angle whose cosine is $\frac{E_R}{E_A}$

VII. Formulas for determining true power

A. $P_T = I^2R$

B. $P_T = E_R I_R$

C. $P_T = EI \cos \theta$ or EI (PF) where PF is the power factor

(NOTE: True power is the actual power consumed by resistance and is measured in watts.)

INFORMATION SHEET

VIII. Formulas for determining apparent power

A. $P_A = EI$

B. $P_A = I^2Z$

C. $P_A = E^2/Z$

(NOTE: Apparent power is the power that appears to be used and is measured in volt-amperes.)

IX. Formulas for determining reactive power

A. $P_X = I^2X$

B. $P_X = E_XI_X$

C. $P_X = EI \sin \theta$ where $\sin \theta = E_R/E_A$ or R/X

(NOTE: Reactive power is power that appears to be used by reactive components, but inductors use no power or energy; they take from the circuit to create magnetic lines of force but return to the circuit when current direction reverses.)

X. Formulas for determining power factor

A. $PF = P_T / P_A$

B. $PF = E_X / E_A$

C. $PF = R/Z$

D. $PF = \cos \theta$ where θ is angle between current and voltage

(NOTE: Power factor is the ratio of true power to apparent power.)

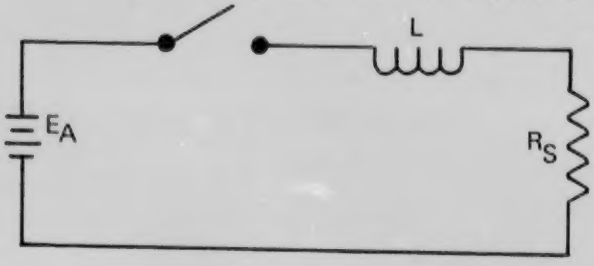
XI. Formula for determining quality factor (Q) or figure of merit of an inductor--

$Q = \frac{X_L}{R_s}$ where X_L is inductive reactance in ohms and R_s is series resistance in ohms of an inductor

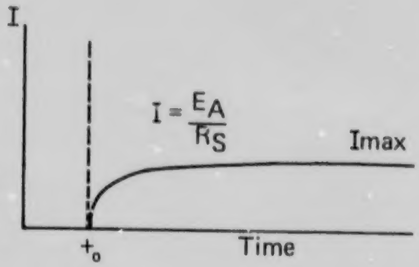
(NOTE: The quality factor (Q) or figure of merit is the measure of a coil's energy storing ability.)

INFORMATION SHEET

XII. Inductive time constants (Transparency 1)



RL Circuit



Current Graph

A. In the RL circuit connected to DC, current does not immediately rise to the Ohm's law value when switch is closed

B. Time required for current to reach maximum value varies:

1. Directly with inductance in henries

2. Inversely with resistance in ohms

C. One time constant (TC) equals L/R

D. Current rises (or falls) 63.2 percent of the value remaining during each time constant; thus, approximately 5TC are required to reach maximum (or minimum) (Transparency 2)

E. Number of time constants = $\frac{Rt}{L}$ where R is resistance in ohms
t is any given time in seconds
L is inductance in henries

(NOTE: The instantaneous voltage across the inductor at a given time equals $e_L = E_A \epsilon^{-Rt/L}$ where ϵ is natural log base (2.718) and the voltage across the resistor equals $e_R = (E_A)(1 - \epsilon^{-Rt/L})$.)

XIII. Universal time constant chart (Transparency 3)

A. Current (or voltage) rising from zero to maximum

1. 1TC--63.2%

2. 2TC--86.5%

3. 3TC--95%

INFORMATION SHEET

    4. 4TC--98%

    5. 5TC--100%

B. Current (or voltage) falling from maximum to zero

    1. 1TC--36.8%

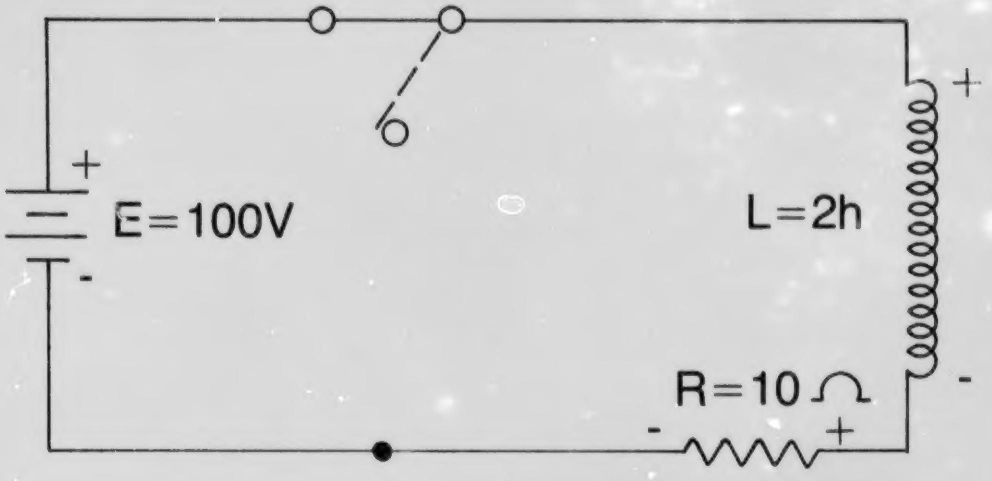
    2. 2TC--13.5%

    3. 3TC--5%

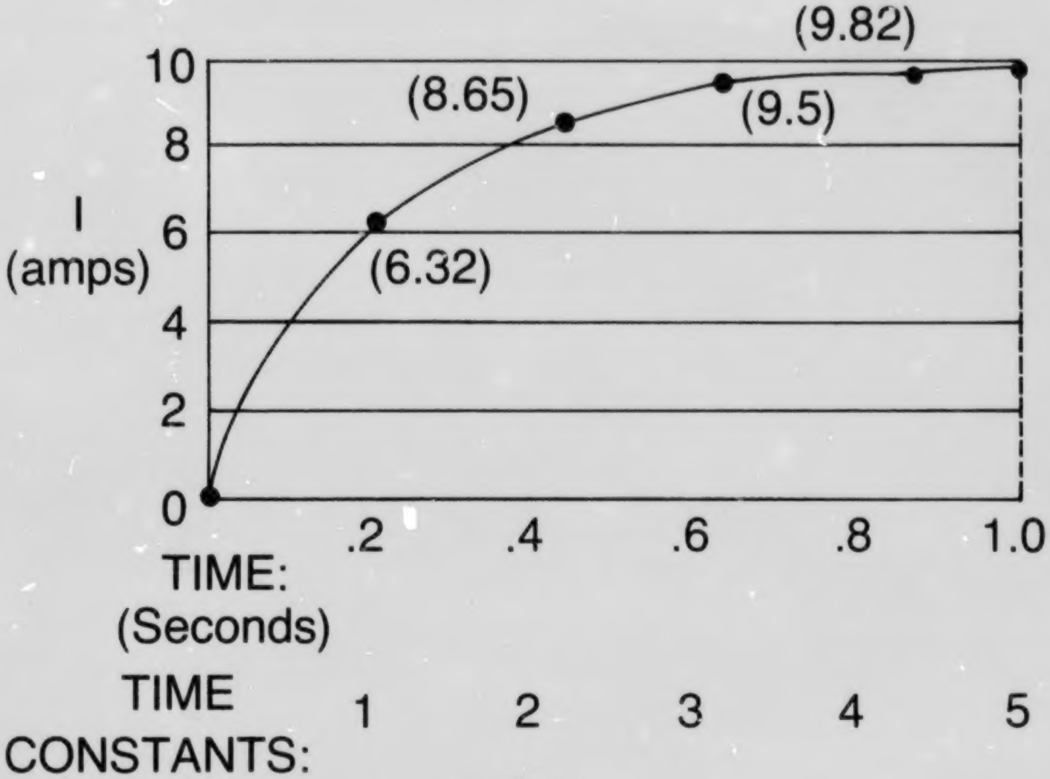
    4. 4TC--2%

    5. 5TC--0%

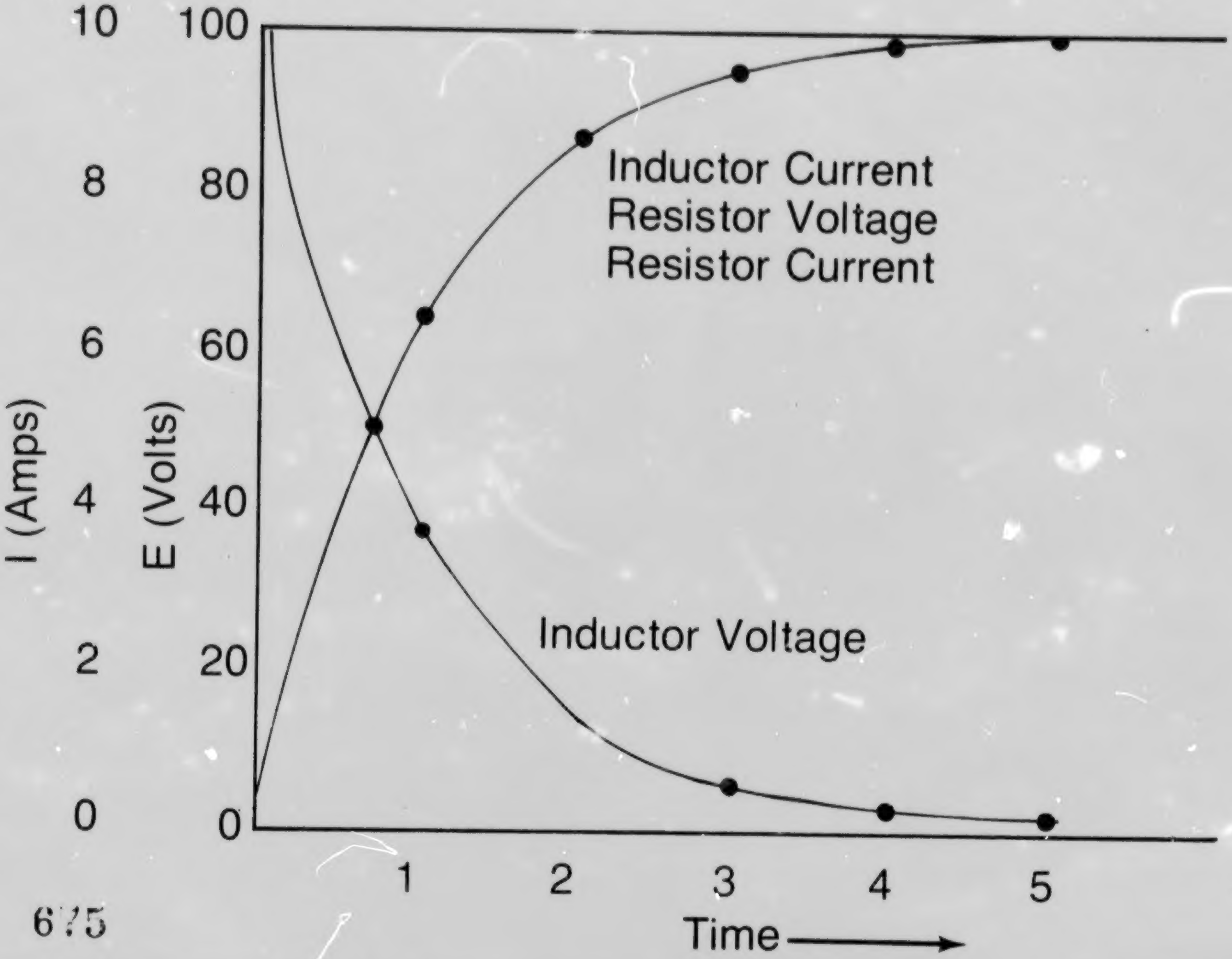
R L Circuit and Current Rise



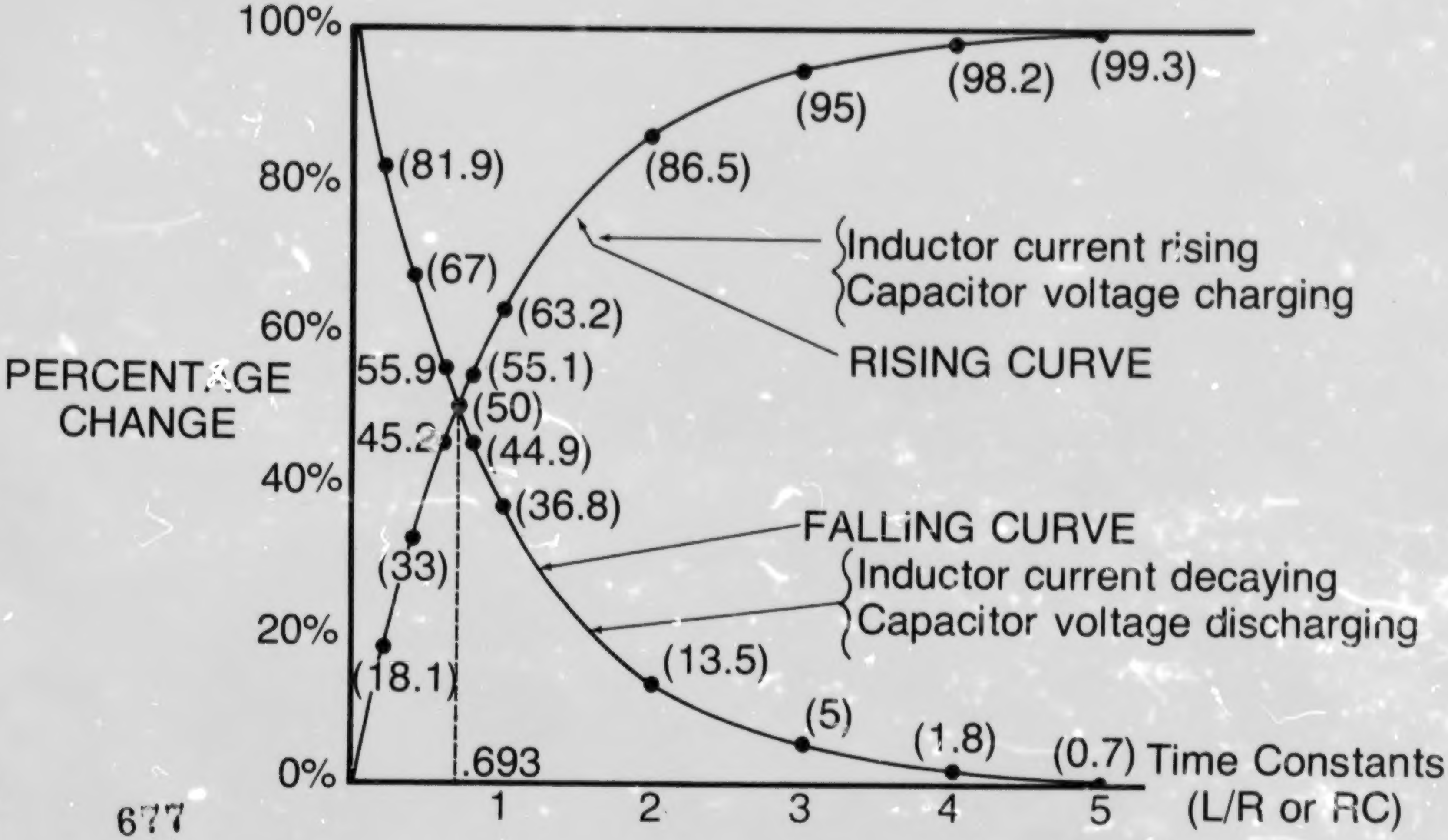
+
E=100V
-
L=2h
+
-
R=10 Ω
-
+



Current and Voltage Relationships in RL Circuits



Universal Time Constant Chart



INDUCTIVE REACTANCE
UNIT IV

ASSIGNMENT SHEET #1--COMPUTE INDUCTIVE REACTANCE

1. Write the formula for computing inductive reactance.

2. Select the unit of measure inductive reactance is expressed in.

   a. Henries

   b. Ohms

   c. Farads

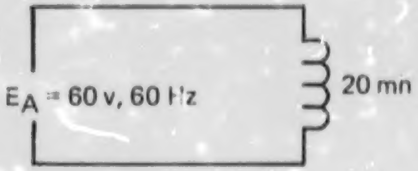
   d. Radians

3. If the frequency of the applied voltage of an RL circuit is increased, the inductive reactance (increases) (decreases).

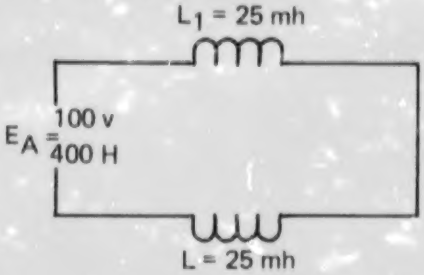
4. If the inductance is increased in a given circuit, the inductive reactance (increases) (decreases).

5. In the following circuits, solve for X_L.

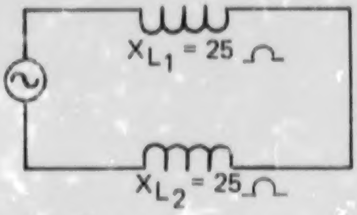
   a. X_L = ________


E_A = 60 v, 60 Hz
20 mn

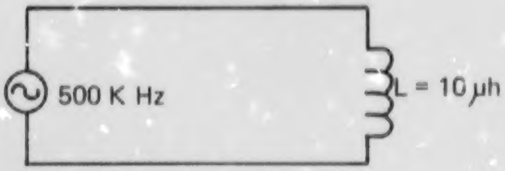
   b. X_L = ________


L_1 = 25 mh
E_A = 100 v 400 H
L = 25 mh

   c. X_{LT} = ________


X_{L_1} = 25 Ω
X_{L_2} = 25 Ω

   d. X_L = ________


500 K Hz
L = 10 μh

INDUCTIVE REACTANCE
UNIT IV

ASSIGNMENT SHEET #2--COMPUTE APPLIED VOLTAGE AND IMPEDANCE OF RL CIRCUITS

1. Select true statements relating to RL series circuits by placing an "X" in the appropriate blanks.

   _____a. The current in a series RL circuit is the same in the inductor as in the resistor (at all times)

   _____b. In a purely inductive circuit, the current lags the applied voltage by 90 degrees ($\pi/2$ radians)

   _____c. In a practical circuit containing inductance and resistance, the current will lag the voltage by an angle somewhere between almost zero and almost 90 degrees

   _____d. The voltage across the inductor is always in phase with the applied voltage

   _____e. The voltage across the resistor is always in phase with the applied voltage

   _____f. The voltage across the resistor is always in phase with the current flowing through the resistor

   _____g. The applied voltage is the vector sum of the voltage drops across the resistor and the inductor

   _____h. If 100 volts is applied to a circuit having 50 ohms of resistance and 50 ohms of inductive reactance, there will be 50 volts across the resistor and 50 volts across the inductor

2. If there are 10 ohms of resistance in series with 10 ohms of inductive reactance, the circuit impedance will be _______________ ohms

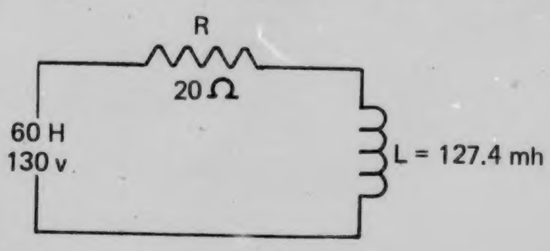
3. If there is a 30 volt drop across the resistor and a 40 volt drop across the inductor in a series RL circuit, the applied voltage is _______________ volts, and the cosine of the phase angles is _____________________. (Remember, the cosine of the phase angle equals E_R/E_A.)

4. Solve as indicated.

   a. X_L = ____________________

   b. Z = ____________________

   c. I = ____________________



ASSIGNMENT SHEET #2

d. E_R = ____________________

e. E_L = ____________________

INDUCTIVE REACTANCE
UNIT IV

ASSIGNMENT SHEET #3--COMPUTE POWER IN REACTIVE CIRCUITS

1. List three ways to compute true power.

   a.

   b.

   c.

2. List three ways to compute apparent power.

   a.

   b.

   c.

3. List three ways to compute reactive power.

   a.

   b.

   c.

4. List three ways to compute power factor. (i.e., cosine θ)

   a.

   b.

   c.

5. In a series circuit with only a pure inductor, if there are 100 volts and 10 amperes applied, the true power consumed is ____________________ watts.

6. Solve as indicated in the following circuit.

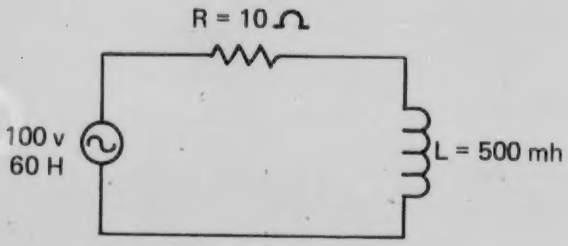
   a. X_L = ____________

   b. Z = ____________

   c. I = ____________

   d. E_R = ____________

   e. E_L = ____________



ASSIGNMENT SHEET #3

f. PF = ____________

g. P_A = ____________

h. P_T = ____________

i. P_X = ____________

INDUCTIVE REACTANCE
UNIT IV

ASSIGNMENT SHEET #4--COMPUTE THE Q OF INDUCTORS

1. State the formula for computing Q.

   Q = ______________________________

2. Two inductors have the same value of L but one has more resistance in its windings than the other. The one with the most resistance has the (higher) (lower) Q.

3. Select true statements regarding the Q of inductors by placing an "X" in the appropriate blanks.

   _____a. All inductors have some resistance.

   _____b. High Q coils usually have relatively little resistance.

   _____c. In general, high Q coils have greater energy storage ability than do low Q coils.

   _____d. Since Q equals X_L divided by R_s, an inductor having a Q of "100" means that it has 100 ohms.

4. A coil is measured with a DC ohmmeter as having 0.5 ohms resistance. If the coil has an X_L of 300 ohms, the Q is ____________.

5. Increasing the angular velocity slightly (increases) (decreases) the Q of the coil.

6. An inductor has an internal resistance of 1/2 ohm and is rated at 500 mh. If 10 volts at 60 hertz is applied, the Q of the inductor is ____________________.

INDUCTIVE REACTANCE
UNIT IV

ASSIGNMENT SHEET #5--SOLVE TIME CONSTANT PROBLEMS

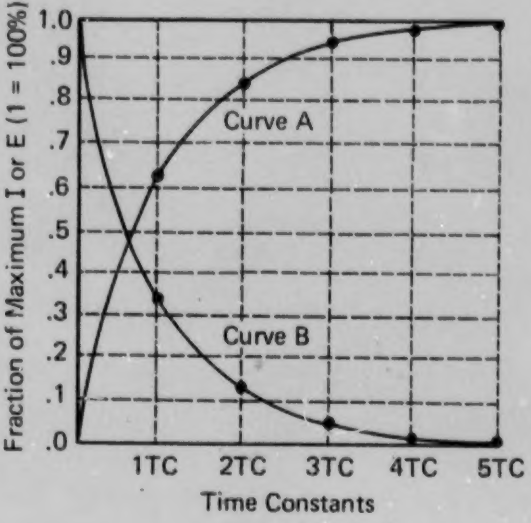
1. The percentages in the universal time constant chart show in a series RL DC circuits as (check the correct statements.)

   _____a. current increase on Curve B

   _____b. current increase on Curve A

   _____c. current decrease on Curve B

   _____d. current decrease on Curve A



2. Refer to the chart. How many time constants are required for

   _____a. Current rise to maximum value?

   _____b. Current decay from maximum to zero?

3. Refer to Curve A only in the chart. At 1TC, what is the percentage of current increase? _______________

4. What is the percentage of current increase at 2TC? _______________

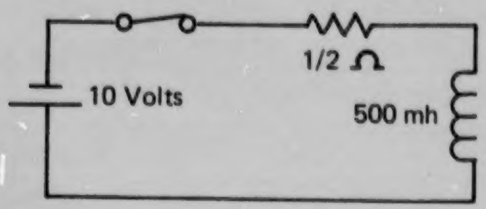
5. What is the percentage of rise at 3TC? __________ 4TC? __________

6. In effect, when the switch is turned off and current starts to decay, it will have dropped to what percentage of its maximum value at 1TC?(the first percentage on the B curve). _______________

7. What is the percentage decay at 2TC? __________ 3TC? __________

ASSIGNMENT SHEET #5

8. Using the following circuit and the universal time constant chart, answer the questions below the circuit.



a. The maximum current that will flow in the circuit is ____________ amps.

b. The time for one time constant is ______________________________.

c. The time required to reach the maximum current after switch closure is ________.

d. The time required to reach 19 amperes is ___________________ seconds after switch closure.

INDUCTIVE REACTANCE
UNIT IV

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

1. $X_L = \omega L$ or $X_L = 2\pi fL$
2. b
3. Increases
4. Increases
5. a. 7.54 ohms
   b. 125.7 ohms
   c. 50 ohms
   d. 31.4 ohms

Assignment Sheet #2

1. a. True
   b. True
   c. True
   d. False
   e. False
   f. True
   g. True
   h. False

2. 14.1 ohms

3. 50 volts; 30/50 or 0.6

4. a. 48 ohms
   b. 52 ohms
   c. 2.5 amperes
   d. 50 volts
   e. 120 volts

Assignment Sheet #3

1. a. $P_T = I^2R$ b. $P_T = E_R I_R$ c. $P_T = EI\ (PF)$ or $EI\cos\theta$

2. a. $P_A = EI$ b. $P_A = I^2Z$ c. $P_A = (E^2)/Z$

3. a. $P_X = I^2X$ b. $P_X = E_X I_X$ c. $P_X = EI \sin\theta$

4. a. $PF = P_T/P_A$ b. $PF = E_R/E_A$ c. $PF = R/Z$

5. 0

6. a. 188.5 ohms
   b. 188.8 ohms
   c. .53 amps
   d. 5.3 volts
   e. 99.9 volts
   f. 0.053
   g. 53 volt-amperes
   h. 2.81 watts
   i. 52.95 vars

Assignment Sheet #4

1. $Q = X_L/R_s$
2. Lower
3. a. True
   b. True
   c. True
   d. False
4. 600
5. Increases
6. 377

Assignment Sheet #5

1. b, c
2. a. 5
   b. 5
3. 63.2%
4. 86.5%
5. 95%, 98%
6. 36.8%
7. 13.5%, 5%
8. a. 20 amperes
   b. 1 second
   c. 5 seconds
   d. 3 seconds

INDUCTIVE REACTANCE
UNIT IV

JOB SHEET #1–SHOW THE EFFECT OF INDUCTANCE IN AC CIRCUITS

I. Tools and materials

   A. Filter choke approximately 2h or larger

   B. 75 ohm, 1 watt resistor

   C. DC and AC milliammeters

   D. Multimeter

   E. AC and DC power supplies

II. Procedure

   A. Connect the 75 ohm resistor and DC ammeter in series with the DC power supply

   B. Adjust the voltage until there are 5 volts across the resistor

   C. Record the ammeter indication; then compute R_{DC}

   (NOTE: $R_{DC}=E/I$.)

   D. Connect the 75 ohm resistor and AC ammeter in series with the AC power supply

   E. Adjust the voltage until there are 5 volts across the resistor; then record the current from the ammeter and compute R_{AC}

   (NOTE: $R_{AC} = E/I$.)

   F. Compare R_{DC} and R_{AC} and explain differences noted, if any

   G. Connect the filter choke (inductor) and DC ammeter in series with the DC power supply

   H. Adjust the DC power supply until there are 5 volts across the choke; read the current indication on the ammeter and compute $Z_{L(DC)}$

   (NOTE: $Z_{L(DC)} = E_L/I_L$.)

   I. Repeat step H using the AC ammeter and AC power supply and compute $Z_{L(AC)}$

   (NOTE: $Z_{L(AC)} = E_L/I_L$.)

   J. Compare the current recorded in step H with that recorded in Step I and explain any differences noted

JOB SHEET #1

K. Use the filter choke value (henries) and the voltage frequency to compute X_L

L. Compare the computed X_L (Step K) with the DC impedance (Step H) and with the AC impedance (Step I)

M. Explain any differences noted

INDUCTIVE REACTANCE
UNIT IV

JOB SHEET #2--SOLVE FOR VALUES OF AN OPERATING RL CIRCUIT

I. Tools and materials

   A. Filter choke approximately 2h or larger

   B. Resistor, 750 ohms, 5 watts

   C. AC power supply

   D. AC ammeter

   E. Multimeter

   F. Switch

II. Procedure

   A. Measure and record the resistance of the inductor (filter choke) with your ohmmeter (NOTE: This is the DC resistance (R_{DC}) of the coil.)

   B. Measure and record the value of the 750-ohm resistor

   C. Connect the circuit as shown in the following schematic (Figure 1)

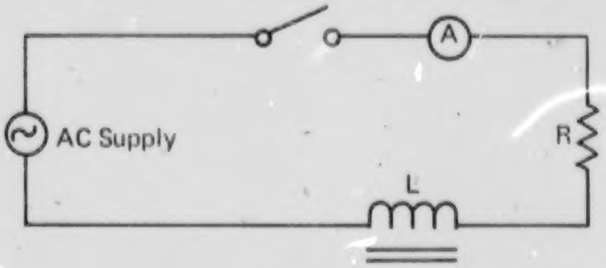


FIGURE 1

   D. Connect an AC voltmeter across the AC supply, close the switch and adjust the AC input until the meter indicates 100 volts

   E. Read and record the voltage across R (E_R)

   F. Read and record the voltage across L (E_L)

   G. Read and record the applied voltage (across both R and L)

   H. Read and record the current flowing in the circuit (I)

JOB SHEET #2

I. Compute the value of X_L

J. Add the coil's DC resistance (Step A) and the resistor value (Step B); then multiply this value by the circuit current and compare the result with the applied voltage (E_A) observed in step G

K. Arithmetically add E_R (Step E) and E_L (Step F) and compare with E_A (Step G)

L. Repeat Step K but use the formula $E_A = \sqrt{E_R^2 + E_L^2}$

M. Multiply the current (Step H) and the computed value of X_L (Step I) and compare the result with E_L (Step F)

N. Make a vector diagram to scale (Figure 2) showing the values of E_R, E_L, and E_A, letting E_A be the hypotenuse of the right triangle formed by sides E_R and E_L; explain any differences noted

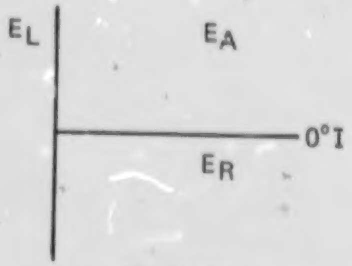


FIGURE 2

O. Discuss and explain differences observed with your instructor

INDUCTIVE REACTANCE
UNIT IV

NAME ______________________________

TEST

1. Match the terms on the right with their correct definitions.

_____a. The angle that the current leads or lags the voltage in an AC circuit

_____b. The product of reactive voltage and amperes in an AC circuit

_____c. Opposition to current including both resistance and reactance

_____d. Opposition to current resulting in energy dissipation

_____e. Circuit opposition caused by inductance

_____f. The product of volts and amperes in an AC circuit

_____g. The rate of change of cyclical motion

_____h. Opposition to current caused by voltage or current changes not resulting in energy dissipation

_____i. The time required for an exponential quantity to change by an amount equal to 0.632 times the total change that will occur

_____j. The ratio of true power to apparent power in an AC circuit

_____k. The rate of energy consumption in a circuit

1. Resistance
2. Reactance
3. Impedance
4. Inductive reactance
5. Power
6. Reactive power
7. Apparent power
8. Power factor
9. Phase angle
10. Angular velocity
11. Time constant

2. Match the symbols on the right with their correct definitions.

______a.	Reactance in ohms	1. X_L
______b.	Inductive reactance in ohms	2. VARS
______c.	Frequency in hertz	3. Z
______d.	Resistance in ohms	4. f
______e.	Angular velocity in radians per second	5. ω
______f.	Impedance in ohms	6. X
______g.	Radians in one cycle	7. PF
______h.	Reactive apparent power	8. R
______i.	Power factor	9. 2π

3. List three factors needed to compute inductive reactance, X_L.

a. ____

b. ____

c. ____

4. State the formula for computing inductive reactance.

5. Select true statements describing current and voltage relationships in RL circuits by placing an "X" in the appropriate blanks.

______a. Current leads voltage by 90° in a pure inductive circuit

______b. Current lags voltage by 90° in a pure inductive circuit

______c. Current and voltage are in phase in a pure inductive circuit

______d. Current and voltage are in phase in a pure resistive circuit

______e. Current lags voltage between 0° and 90° in an RL circuit, depending upon relative amounts of R and L present, and frequency of applied voltage or current

6. Compute the applied voltage and impedance in a series RL circuit in which the voltage across the resistor is 50 volts, the voltage across the inductor is 120 volts, and the current is 13 milliamps.

   a. Applied voltage is ________________ volts

   b. Impedance is ________________ ohms

7. State three formulas for determining true power.

   a. ________________

   b. ________________

   c. ________________

8. State three formulas for determining apparent power.

   a. ________________

   b. ________________

   c. ________________

9. State three formulas for determining reactive power.

   a. ________________

   b. ________________

   c. ________________

10. State four formulas for determining power factor.

    a. ________________

    b. ________________

    c. ________________

    d. ________________

11. State the formula for determining quality factor (Q) or figure of merit of an inductor.

12. Select true statements concerning inductive time constants by placing an "X" in the appropriate blanks.

_____a. In the RL circuit connected to DC, the current immediately rises to the Ohm's law value when switch is closed

_____b. The time required for current to reach maximum value varies inversely with inductance in henries

_____c. The time required for current to reach maximum value varies inversely with resistance in ohms

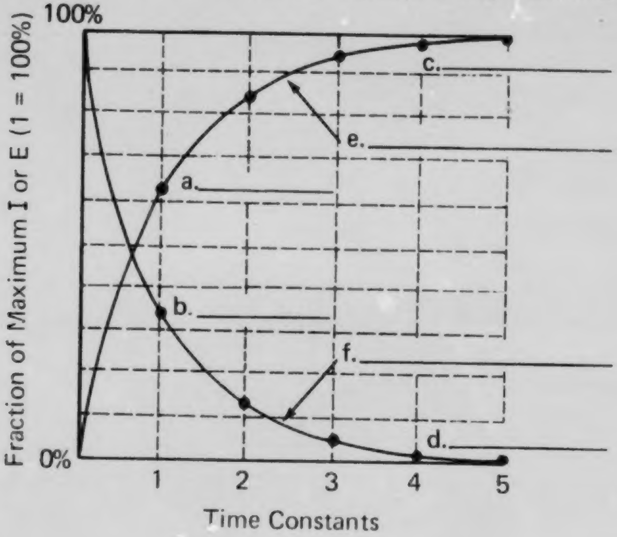
_____d. During each time constant, the current rises (or falls) 63.2 percent of the value remaining

_____e. During each time constant, the current rises (or falls) 36.8 percent of the value remaining

_____f. One time constant equals L/R

_____g. One time constant equals X_L/R

13. Complete the labels on a universal time constant chart to indicate current (or voltage) rising from zero to maximum and current or voltage falling from maximum to zero.



14. Compute inductive reactance.

15. Compute applied voltage and impedance of RL circuits.

16. Compute power in reactive circuits.

17. Compute the Q of inductors.

18. Solve time constant problems.

19. Demonstrate the ability to:

    a. Show the effect of inductance in AC circuits.

    b. Solve for values of an operating RL circuit.

    (NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

INDUCTIVE REACTANCE
UNIT IV

ANSWERS TO TEST

1. a. 9
   b. 6
   c. 3
   d. 1
   e. 4
   f. 7
   g. 10
   h. 2
   i. 11
   j. 8
   k. 5

2. a. 6
   b. 1
   c. 4
   d. 8
   e. 5
   f. 3
   g. 9
   h. 2
   i. 7

3. a. ω --Angular velocity in radians per second
   b. L--Inductance in henries
   c. f--Frequency in hertz

4. $X_L = \omega L = 2\pi fL$

5. b, d, e

6. a. 130 volts
   b. 10,000 ohms

7. a. $P_T = I^2R$
   b. $P_T = E_RI_R$
   c. $P_T = EI \cos\theta$ or EI (PF) where PF is the power factor

8. a. $P_A = EI$
   b. $P_A = I^2Z$
   c. $P_A = E^2/Z$

9. a. $P_X = I^2X$
   b. $P_X = E_XI_X$
   c. $P_X = EI \sin 0$ where $\sin 0 = E_R/E_A$ or R/X

10. a. $PF = P_T/P_A$
    b. $PF = E_X/E_A$
    c. $PF = R/Z$
    d. $PF = \cos\theta$ where θ is angle between current and voltage

11. $Q = \dfrac{XL}{R_s}$ where X_L is inductive reactance in ohms and R_s is series resistance in ohms

12. c, d, f

13. a. 63.2
    b. 36.8
    c. 98.2
    d. 1.8
    e. Rising curve
    f. Falling curve

14. Evaluated to the satisfaction of the instructor.

15. Evaluated to the satisfaction of the instructor.

16. Evaluated to the satisfaction of the instructor.

17. Evaluated to the satisfaction of the instructor.

18. Evaluated to the satisfaction of the instructor.

19. Performance skills evaluated to the satisfaction of the instructor.

CAPACITANCE
UNIT V

UNIT OBJECTIVE

After completion of this unit, the student should be able to select true statements concerning the functions of capacitance in electric circuits and state formulas for capacitance. The student should also be able to test capacitors with an ohmmeter and determine the effect of AC and DC on capacitors. This knowledge will be evidenced by correctly performing the procedures outlined in the assignment and job sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms associated with capacitance with their correct definitions.
2. Match symbols and abbreviations concerning capacitance with their correct meanings.
3. Select true statements describing the functions of capacitance in electric circuits.
4. Select true statements concerning capacitor construction.
5. Select true statements regarding the DC charging and discharging of a capacitor.
6. Select true statements concerning the formula for capacitance.
7. State the formula for total capacitance of capacitors in parallel.
8. State the formula for total capacitance of several unequal capacitors in series.
9. State the formula for total capacitance of two capacitors in series.
10. State the formula for total capacitance of capacitors of equal value in series.
11. Name types of capacitors.
12. State two rules concerning capacitor color coding.
13. Compute capacitance values.
14. Demonstrate the ability to:
    a. Test capacitors with an ohmmeter.
    b. Examine the construction of a capacitor.
    c. Determine the effect of AC and DC on capacitors.

CAPACITANCE
UNIT V

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information, assignment, and job sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information and assignment sheets.

VI. Demonstrate and discuss the procedures outlined in the job sheets.

VII. Demonstrate the operation of capacitance measuring instruments.

VIII. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:
   - A. Objective sheet
   - B. Information sheet
   - C. Transparency masters
     1. TM 1--Capacitor Construction
     2. TM 2--Plate Area
     3. TM 3--Plate Distance
     4. TM 4--Effect of the Dielectric
     5. TM 5--Electric Field Effect on Dielectrics
   - D. Assignment Sheet #1--Compute Capacitance Values
   - E. Answers to assignment sheet
   - F. Job sheets
     1. Job Sheet #1--Test Capacitors With an Ohmmeter
     2. Job Sheet #2--Examine the Construction of a Capacitor
     3. Job Sheet #3--Determine the Effect of AC and DC on Capacitors

   G. Test

   H. Answers to test

II. References:

   A. Grob, Bernard. *Basic Electronics.* New York: McGraw-Hill, 1977.

   B. *Basic Electricity/Electronics, Book 2.* Natchitoches, LA: Louisiana Vocational Curriculum Development Center, 1979.

CAPACITANCE
UNIT V

INFORMATION SHEET

I. Terms and definitions

   A. Capacitance--The property of conductors and dielectrics that permits storage of electrical charges when voltage exists between the conductors

   B. Capacitor--A device which introduces capacitance into an electric circuit

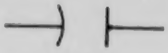
   C. Dielectric--The insulating material between the plates of a capacitor

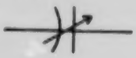
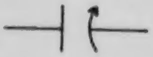
   D. Farad--The unit of capacitance

   E. Coulomb--The unit of quantity of electricity equal to 6.28×10^{18} electrons

   F. Dielectric constant--The relative ability of an insulator to concentrate electric flux

II. Symbols and abbreviations

   A. Fixed capacitor-- 

   B. Variable capacitor--  or 

   C. Farad--f (also fd, F, or Fd)

   D. Capacitance--C

   E. Charge--Q or q

   F. Dielectric constant--K

III. Functions of capacitance

   A. When the voltage increases, capacitance tries to hold it down

   B. When the voltage decreases, capacitance tries to hold it up

   C. In addition to opposing a change in voltage, capacitance can be used to:

      1. Store electrical energy

      2. Block the flow of DC

      3. Permit the apparent flow of AC in the circuit

INFORMATION SHEET

IV. Capacitor construction (Transparency 1)

A. The larger the plate area the larger the capacitance (Transparency 2)

B. The closer the plates the greater the capacitance (Transparency 3)

C. The larger the dielectric constant, the larger the capacitance (Transparencies 4 and 5)

D. Conclusions:

1. Capacitance is directly proportional to area of plates

2. Capacitance is directly proportional to relative dielectric constant

3. Capacitance is inversely proportional to distance between plates

(NOTE: $C = .224 \frac{KA}{d} (n - 1)$

where C is capacitance in picofarads
K is dielectric constant
A is plate area
d is distance between plates
n is number of plates)

V. DC charging and discharging of a capacitor (Transparency 5)

A. Applying DC voltage results in: (Figure 1)

1. Charging current flowing from one plate to the other

2. Dielectric electrostatic field

B. Discharging results in: (Figure 2)

1. Capacitor acting as a source of energy

2. Discharge current flowing from one plate to other

3. Removal of electrostatic field

INFORMATION SHEET

C. Current does not flow through the capacitor
(CAUTION: A charged capacitor is an energy source and can result in a shock if the leads are touched.)

CHARGING

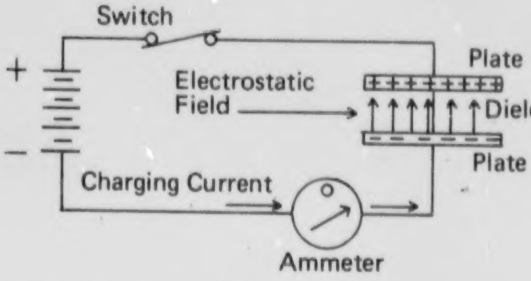

Switch
+
−
Electrostatic Field
Plate
Dielectric
Plate
Charging Current
Ammeter

FIGURE 1

DISCHARGING

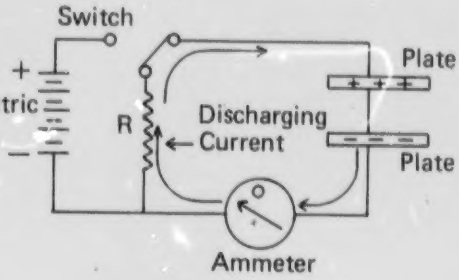

Switch
+
−
R
Plate
Discharging Current
Plate
Ammeter

FIGURE 2

VI. Formula for capacitance

A. $Q = C \times E$ or $C = Q/E$; that is, farads equal coulombs per volt

1. Q is charge in coulombs
2. C is capacitance in farads
3. E is voltage in volts

B. Capacitors usually are made in:

1. Microfarads (μf) or 1×10^{-6} farads
2. Picofarads (pf) or 1×10^{-12} farads (sometimes written as "$\mu\mu f$")

(NOTE: A farad is a large unit.)

VII. Formula for total capacitance of capacitors in parallel--

$$C_T = C_1 + C_2 + C_3 \ldots$$

(NOTE: The effect is the same as increasing plate area and the voltage breakdown of parallel capacitors equals the lowest value of any one.)

VIII. Formula for total capacitance of several unequal capacitors in series--

$$C_T = \frac{1}{1/C_1 + 1/C_2 \ldots}$$

(NOTE: The effect is the same as increased spacing between plates.)

INFORMATION SHEET

IX. Formula for total capacitance of two capacitors in series--

$$C_T = \frac{C_1 \times C_2}{C_1 + C_2}$$

X. Formula for total capacitance of capacitors of equal size in series--

$$C_T = \frac{C_1}{n}$$

(NOTE: Capacitors in parallel are computed like resistors in series, and capacitors in series are computed like resistors in parallel.)

XI. Types of capacitors

A. Air dielectric

B. Paper

C. Mica

D. Ceramic

E. Electrolytic (polarized)

(NOTE: Electrolytic capacitors can be made of aluminum, tantalum, or niobium.)

XII. Capacitor color coding

A. Color code values are the same as resistor color codes

B. Color code values are always expressed in pf units

Capacitor Construction

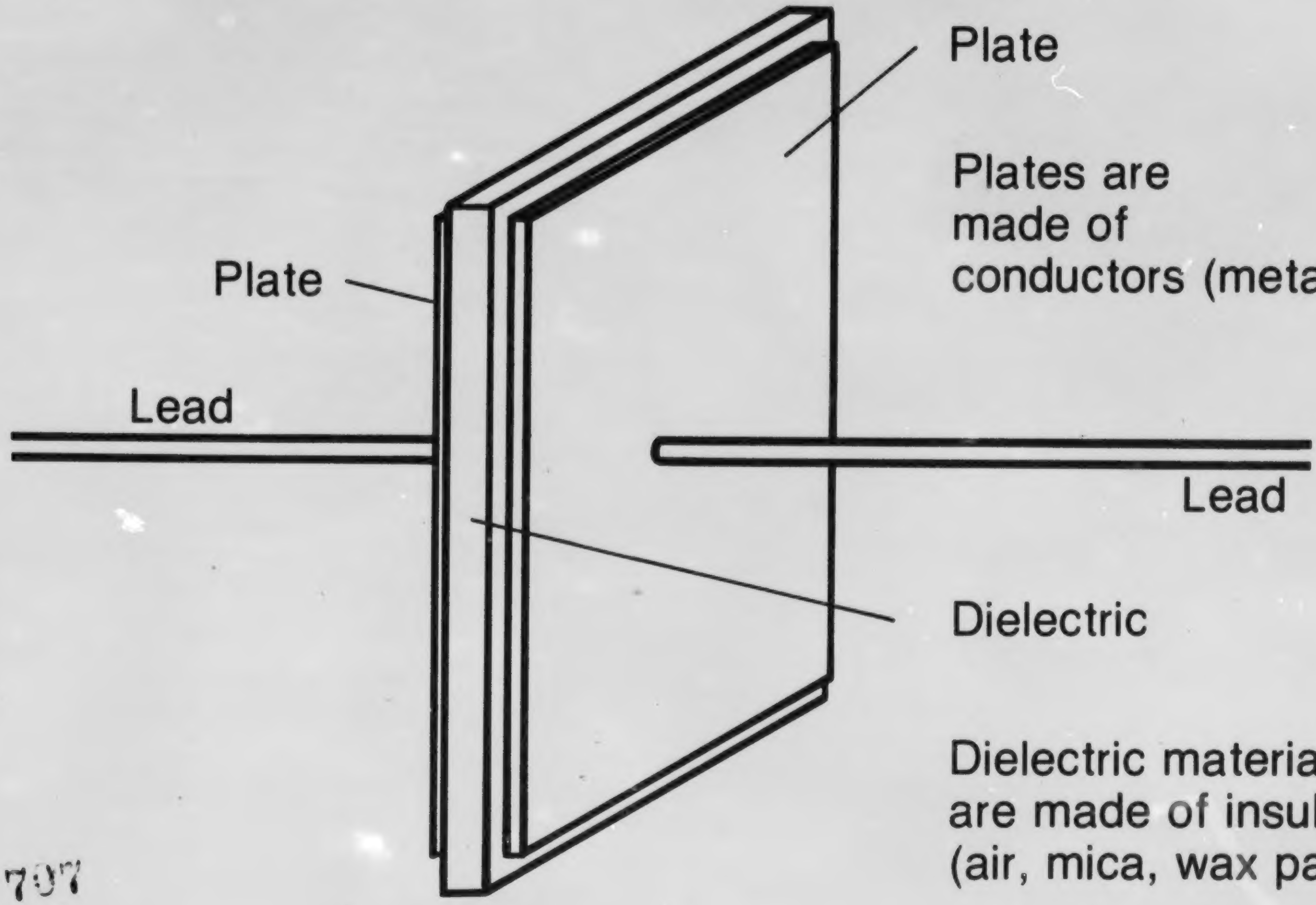
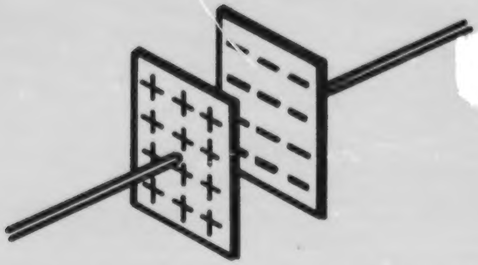


Plate
Plate
Lead
Lead
Dielectric

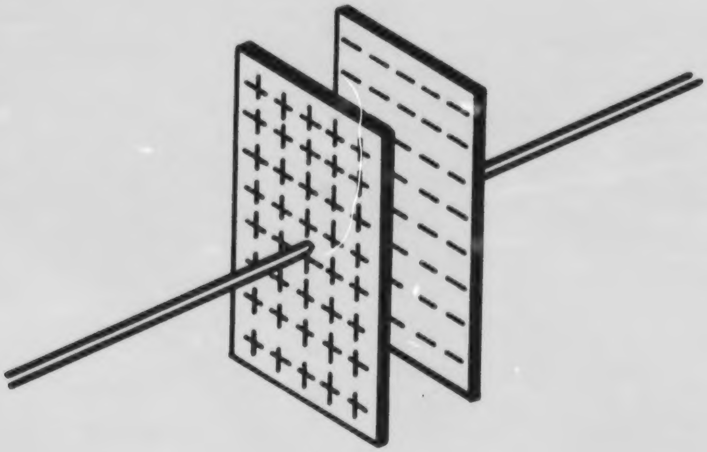
Plates are made of conductors (metals)

Dielectric materials are made of insulators (air, mica, wax paper)

Plate Area

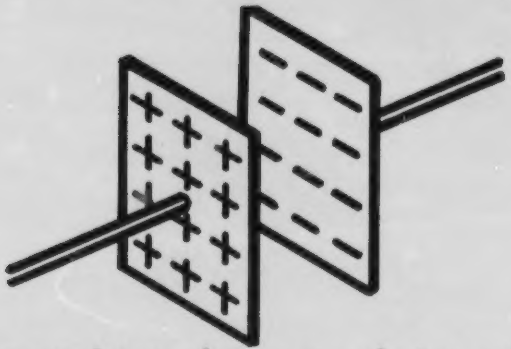


Larger plates hold more electrons.

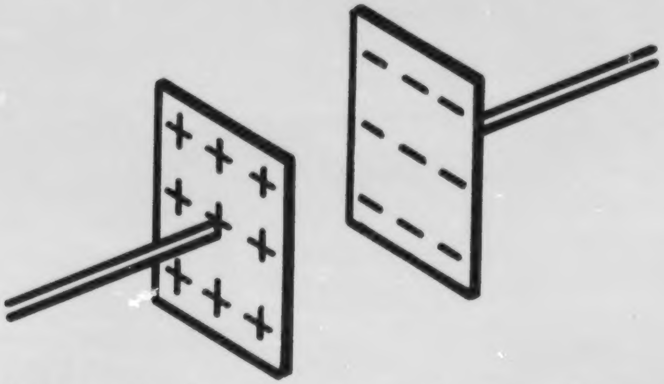


Increased plate area increases capacitance.

Plate Distance



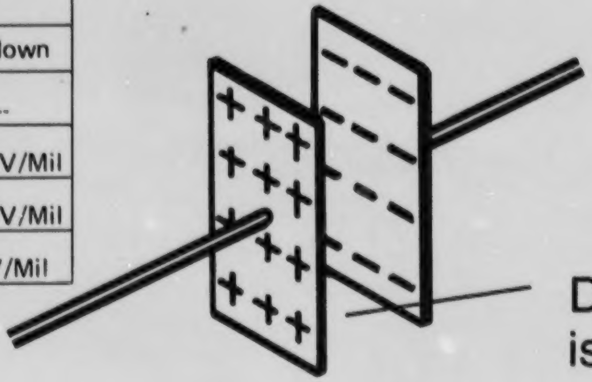
The distance between two charges determines their effect on one another.

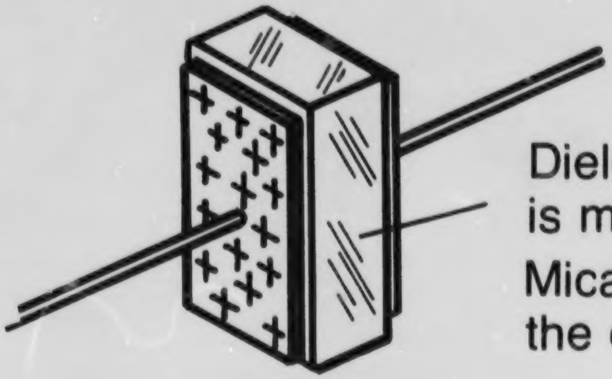


Increasing the distance between the plates decreases capacitance.

Effect of the Dielectric

Typical Dielectrics		
Type	Constant	Breakdown
Air	1.0	-----
Mica	5.4	5000V/Mil
Teflon	2.1	1500V/Mil
Paper	3.0	200V/Mil

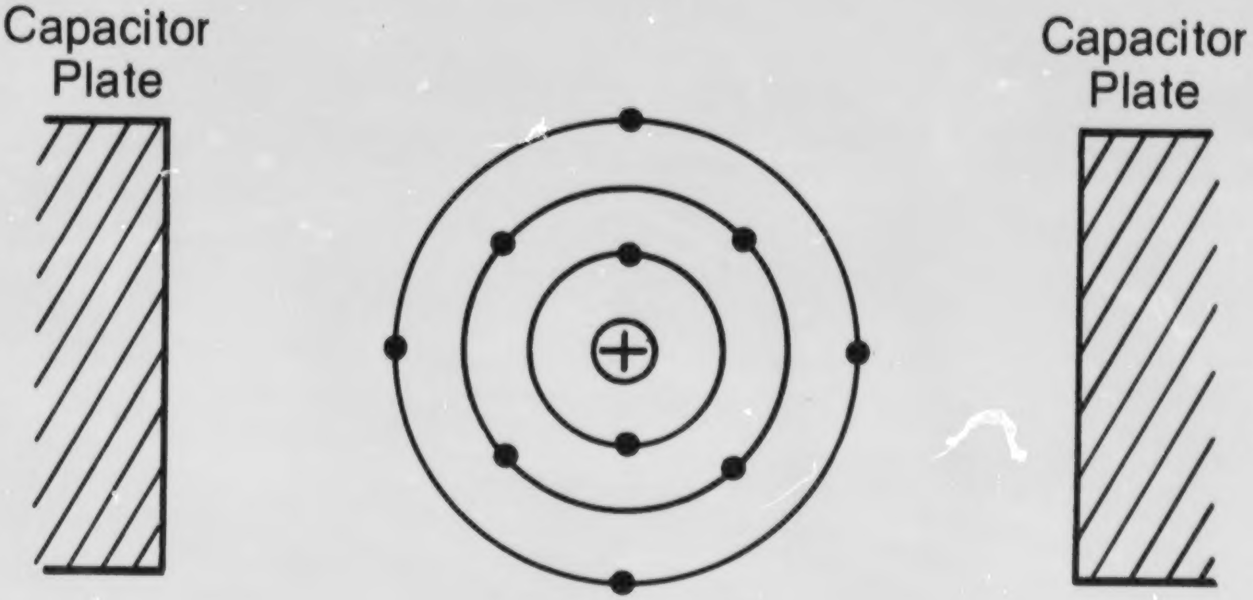

Dielectrical material is air.


Dielectrical material is mica.

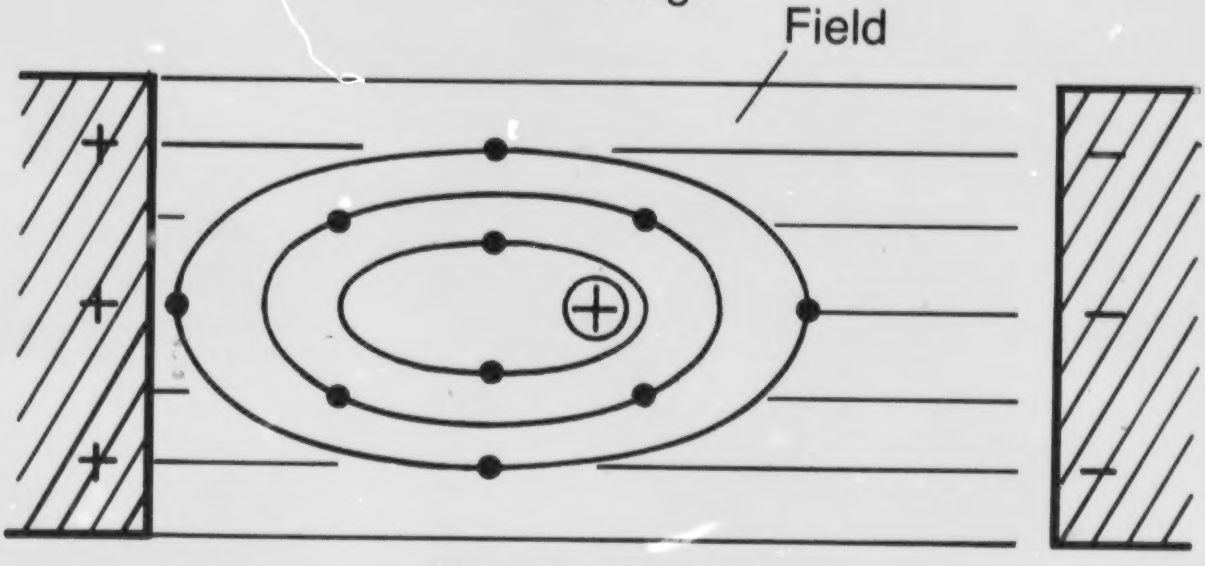
Mica dielectric increases the capacitance.

Changing the dielectric material changes the capacitance.

Electric Field Effect on Dielectrics


Capacitor Plate
Capacitor Plate
+

No Voltage



Voltage Applied

CAPACITANCE
UNIT V

ASSIGNMENT SHEET #1--COMPUTE CAPACITANCE VALUES

1. Write the formula showing the relationship between farads, volts, and electric charge (or quantity).

2. If 50 volts is applied to the following capacitors, compute the amount of charge that will appear on the plates.

   a. 2 f = ____________ coulombs

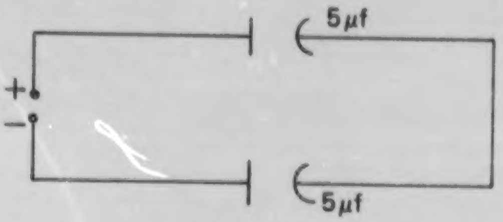
   b. 2μ f = ____________ coulombs

   c. 2 pf = ____________ coulombs

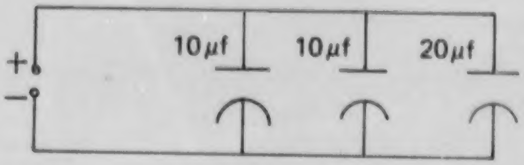
   d. 100μ f = ____________ coulombs

3. In the following circuits solve for the total capacitance, C_T.

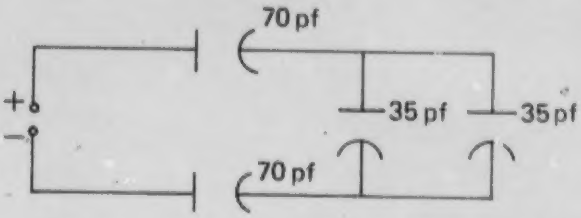
   a. C_T = ____________



   b. C_T = ____________



   c. C_T = ____________



CAPACITANCE
UNIT V

ANSWERS TO ASSIGNMENT SHEET #1

1. $Q = CE$

2. a. 100

   b. 100×10^{-6}

   c. 100×10^{-12}

   d. 5000×10^{-6} (or 5×10^{-3})

3. a. 2.5 μf

   b. 40 μf

   c. 23.3 pf

CAPACITANCE
UNIT V

JOB SHEET #1--TEST CAPACITORS WITH AN OHMMETER

I. Tools and materials

  A. Ohmmeter

  B. 3 capacitors (large, medium, small e.g. less than 0.1 μf)

  C. 1 shorted capacitor

  D. 1 open capacitor

  E. 1 leaky capacitor

II. Procedure

  A. Place the ohmmeter leads across the large (good) capacitor

  B. Note the swing of the needle across the scale to zero and its return to infinity as the capacitor is charged by the ohmmeter battery

  C. Repeat step A and B with the medium and with the small (good) capacitors

  D. Note the smaller deflection of the needle during charge

  E. Place the ohmmeter leads across the open capacitor

  F. Note the lack of any deflection of the ohmmeter needle, indicating no current path

  G. Place the ohmmeter leads across the shorted capacitor

  H. Note that the needle indicates zero ohms resistance (no return toward infinity and thus no charging of the capacitor plates)

  I. Place the ohmmeter leads across the leaky capacitor

  J. Note the return of the needle to some specific resistance indication rather than a return to infinity

  K. Place the ohmmeter leads across the medium sized (good) capacitor and permit the indication to return to infinity

  L. Reverse the ohmmeter leads and observe the difference in initial ohmmeter needle indication

  M. Repeat steps K and L using the small (good) capacitor

  N. Discuss your findings with your instructor

  O. Return tools and materials to proper storage area

CAPACITANCE
UNIT V

JOB SHEET #2--EXAMINE THE CONSTRUCTION OF A CAPACITOR

I. Tools and materials

A. One paper capacitor

B. Electrician's knife

II. Procedure

A. Scrape the wax coating off the exterior of the capacitor

B. Cut through the outermost paper of the capacitor being careful not to cut through more than one "layer" of the capacitor

(CAUTION: Be extremely careful with the knife.)

C. Unroll the capacitor

D. Note the method of attaching the leads and the technique used during manufacture of rolling the two plates

E. Discuss your findings with your instructor

F. Clean work area and return materials to proper storage area

CAPACITANCE
UNIT V

JOB SHEET #3--DETERMINE THE EFFECT OF AC AND DC ON CAPACITORS

I. Tools and materials

A. DC power supply, 0-40v

B. AC power supply, 0-40v

C. Electrolytic capacitor, approximately 10 μf, 100WVDC

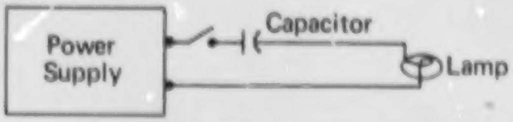
(NOTE: Two 5 μf capacitors may be used.)

D. Miniature lamp and holder

II. Procedure

A. Use the DC power supply, capacitor, and lamp, and connect the circuit as shown in Figure 1

FIGURE 1



B. Turn on the power supply and adjust to 20 volts DC

C. Observe whether or not the lamp lights

D. Return the voltage to zero

E. Turn off the power supply

F. Disconnect the circuit from the DC power supply

G. Connect the circuit to the AC power supply

H. Turn on the AC power supply and adjust to 20 volts AC

I. Observe whether or not the lamp lights and compare with results obtained in Step B

J. Return the voltage to zero

K. Disconnect the circuit

L. Return tools and materials to proper storage area

CAPACITANCE
UNIT V

NAME ______________________________

TEST

1. Match the terms on the right to the correct definitions.

_____a. The insulating material between the plates of a capacitor

_____b. The unit of quantity of electricity equal to 6.28×10^{18} electrons

_____c. The property of conductors and dielectrics that permits storage of electrical charges when voltage exists between the conductors

_____d. A device which introduces capacitance into an electric circuit

_____e. The unit of capacitance

_____f. The relative ability of an insulator to concentrate electric flux

1. Capacitance
2. Capacitor
3. Dielectric
4. Dielectric constant
5. Farad
6. Coulomb

2. Match the symbols and abbreviations on the right with their correct meanings.

_____a. Fixed capacitor

_____b. Variable capacitor

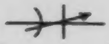
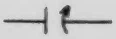
_____c. Farad

_____d. Capacitance

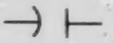
_____e. Charge

_____f. Dielectric constant

1. K

2.  or 

3. Q or q

4. 

5. C

6. f

3. Select true statements describing the functions of capacitance in electric circuits by placing an "X" in the appropriate blanks.

_____a. Stores electrical energy

_____b. Permits the flow of DC

_____c. Blocks the flow of DC

_____d. Permits the apparent flow of AC in the circuit

_____e. Blocks the flow of AC

_____f. When voltage increases, capacitance tries to hold it up

4. Select true statements concerning capacitor construction by placing an "X" in the appropriate blanks.

    ______a. The larger the plate area the larger the capacitance

    ______b. The closer the plates the greater the capacitance

    ______c. The larger the dielectric constant, the smaller the capacitance

    ______d. Capacitance is directly proportional to area of plates

    ______e. Capacitance is inversely proportional to area of plates

    ______f. Capacitance is directly proportional to relative dielectric constant

    ______g. Capacitance is inversely proportional to relative dielectric constant

    ______h. Capacitance is directly proportional to distance between plates

    ______i. Capacitance is inversely proportional to distance between plates

5. Select true statements regarding the DC charging and discharging of a capacitor by placing an "X" in the appropriate blanks.

    ______a. Charging current flows from one plate to the other through the dielectric

    ______b. When charged, a capacitor has a dielectric electrostatic field

    ______c. There is a small amount of current that flows in the external circuit from one plate to the other when charging and when discharging

    ______d. Discharging removes the electrostatic field

6. Select true statements concerning the formula for capacitance by placing an "X" in the appropriate blanks.

    ______a. Farads equal coulombs per volt

    ______b. Farads equal volts per coulomb

    ______c. Coulombs equal farads per volt

    ______d. Coulombs equal volts per farad

    ______e. Capacitors usually are made in microfarads (μf) or picofarads (pf)

7. State the formula for total capacitance of capacitors in parallel.

8. State the formula for total capacitance of several unequal capacitors in series.

9. State the formula for total capacitance of two capacitors in series.

10. State the formula for total capacitance of capacitors of equal value in series.

11. Name three types of capacitors.

    a. ____________________

    b. ____________________

    c. ____________________

12. State two rules concerning capacitor color coding.

    a. ____________________

    b. ____________________

13. Compute capacitance values.

14. Demonstrate the ability to:

    a. Test capacitors with an ohmmeter.

    b. Examine the construction of a capacitor.

    c. Determine the effect of AC and DC on capacitors.

    (NOTE: If these activities are not accomplished prior to the test, ask your instructor when they should be completed.)

CAPACITANCE
UNIT V

ANSWERS TO TEST

1. a. 3 d. 2
   b. 6 e. 5
   c. 1 f. 4

2. a. 4 d. 5
   b. 2 e. 3
   c. 6 f. 1

3. a, c, d

4. a, b, d, f, i

5. b, c, d

6. a, e

7. $C_T = C_1 + C_2 + C_3 \ldots$

8. $C_T = \dfrac{1}{1/C_1 + 1/C_2 \ldots}$

9. $C_T = \dfrac{C_1 \times C_2}{C_1 \times C_2}$

10. $C_T = \dfrac{C_1}{n}$

11. Any three of the following:

    a. Air dielectric
    b. Paper
    c. Mica
    d. Ceramic
    e. Electrolytic

12. a. Color code values are the same as resistor color codes

    b. Color code values are always expressed in pf units

13. Evaluated to the satisfaction of the instructor

14. Performance skills evaluated to the satisfaction of the instructor

RC TIME CONSTANTS
UNIT VI

UNIT OBJECTIVE

After completion of this unit, the student should be able to complete statements concerning charging and discharging an RC circuit, and match illustrations of waveshapes with the values they reflect. The student should also be able to list the units of measurement on a universal time constant chart, list the units of measurement for various exponential formulas in an RC circuit, and be able to determine the constants of RC circuits and construct a neon bulb flasher. This knowledge will be evidenced by correctly performing the procedures outlined on the assignment and job sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms associated with RC time constants with their correct definitions.
2. Complete statements concerning charging an RC circuit by referring to an illustration.
3. Match illustrations of waveshapes during the charge of an RC circuit with the values they reflect.
4. Complete statements concerning discharging an RC circuit by referring to an illustration.
5. Match illustrations of waveshapes during discharge of an RC circuit with the values they reflect.
6. State the formulas for computing time constant.
7. List the units of measurement of the horizontal and vertical axes on a universal time constant chart.
8. List units of measurement in the exponential formulas for voltage across a capacitor and voltage across a resistor in an RC circuit when the formulas are given.
9. List units of measurement in the exponential formula for the charge current of an RC circuit when the formula is given.
10. List units of measurement in the exponential formula for the voltage across a resistor during discharge of an RC circuit when the formula is given.
11. Review series RC and RL circuit characteristics.

12. Compute RC time constants.

13. Demonstrate the ability to:

    a. Determine time constants of RC circuits.

    b. Construct a neon bulb flasher.

RC TIME CONSTANTS
UNIT VI

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information, assignment, and job sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information and assignment sheets.

VI. Demonstrate and discuss the procedures outlined in the job sheets.

VII. If available, use an oscilloscope to demonstrate the various integrated and differentiated waveshapes and polarities.

VIII. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

   A. Objective sheet

   B. Information sheet

   C. Transparency masters

      1. TM 1–RC Time Constant Circuit

      2. TM 2–Universal Time Constant Chart for RC and RL Circuits

   D. Assignment sheets

      1. Assignment Sheet #1–Review Series RC and RL Circuit Characteristics

      2. Assignment Sheet #2–Compute RC Time Constants

   E. Answers to assignment sheets

F. Job sheets

    1. Job Sheet #1--Determine Time Constants of RC Circuits

    2. Job Sheet #2--Construct a Neon Bulb Flasher

G. Test

H. Answers to test

II. References:

A. Grob, Bernard. *Basic Electronics.* New York: McGraw-Hill, 1977.

B. *Basic Electricity/Electronics.* Natchitoches, LA: Louisiana Department of Vocational Education, 1979.

C. Robertson, L.P. *Instrumentation and Measurements Handbook.* Albuquerque, NM: Sandia Laboratories, 1971.

D. *IEEE Standard Dictionary of Electrical and Electronic Terms.* New York: John Wiley & Sons, 1972.

RC TIME CONSTANTS
UNIT VI

INFORMATION SHEET

I. Terms and definitions

A. Time constant (TC)--Time required to complete 63.2 percent of the total time rise or decay

B. Exponential function--A math expression with a fixed base and with varying exponents (e.g. $y = 2.718^{x}$)

C. RC circuit--A circuit with resistance and capacitance

D. Differentiating circuit--A circuit where the output voltage is proportional to the rate of change of the input voltage

(NOTE: In an RC circuit, the voltage across the resistor is the differentiated output.)

E. Integrating circuit--A circuit producing an output proportional to the integral (accumulation) of one variable with respect to another (usually time)

(NOTE: In an RC circuit, the voltage across the capacitor is the integrated output.)

F. ϵ--The base of the natural logarithms equal to 2.718...

(NOTE: In math the abbreviation used is "e".)

II. Charging an RC circuit (Transparency 1)

A. Charge circuit (Figure 1)

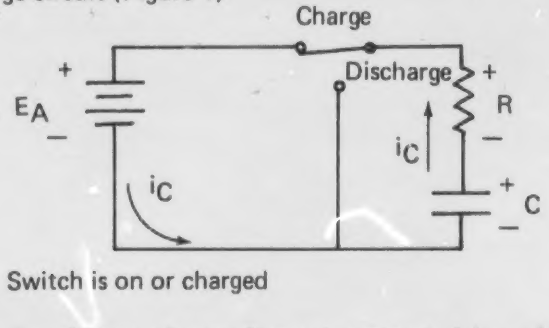


FIGURE 1

1. Switch is on or charged

2. A resistor and capacitor are connected in series with a direct-current voltage source

INFORMATION SHEET

B. At t_o (instant switch is closed)

1. i_C is maximum and equals E_A/R

   (NOTE: i_C is the charging current.)

2. e_R is maximum and equals E_A

3. e_C is zero

C. After about 5 time constants

1. i_C decreases (as e_C approaches value of E_A, i_C approaches zero)

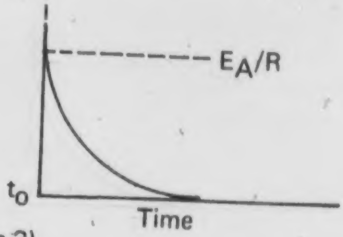
2. e_C increases (as charge on capacitor increases)

3. e_R decreases (as e_C increases because E_A must equal $e_C + e_R$ at all times)

III. Waveshapes during the charge of an RC circuit

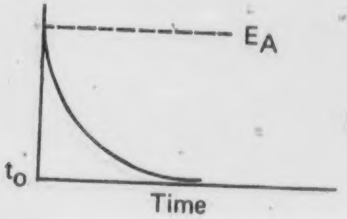
A. i_C and i_R (Figure 2)

FIGURE 2



B. e_R (Figure 3)

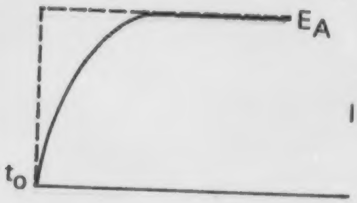
FIGURE 3



Differentiated Output

C. e_C (Figure 4)

FIGURE 4



Integrated Output

INFORMATION SHEET

IV. Discharging an RC Circuit

A. Discharge circuit (Transparency 1)

1. Switch is in discharge position

2. e_C equals E_A

B. At t_o

1. i_d is maximum and equals e_C/R

(NOTE: i_d the discharge current is in direction reverse of i_C.)

2. e_R is maximum and equals i_d R

3. e_C is maximum and begins to decay

C. After about 5 time constants

1. i_d approaches zero exponentially from negative value

2. e_R approaches zero exponentially from negative value

3. e_C approaches zero exponentially from positive value

V. Waveshapes during discharge of an RC circuit

A. i_d (Figure 5)

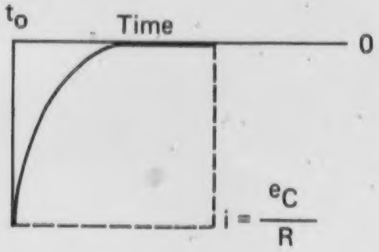


FIGURE 5

INFORMATION SHEET

B. e_R (Figure 6)

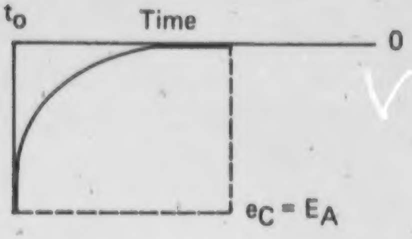


FIGURE 6

C. e_C (Figure 7)

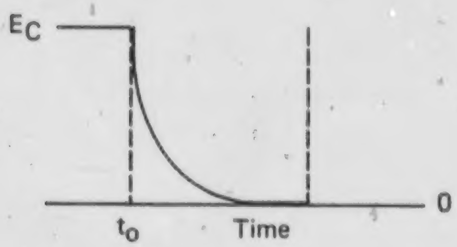


FIGURE 7

VI. Formulas for computing time constant

A. Formula for one time constant--T = RC (where R is in ohms, C is in farads, and T is in seconds)

B. Formula for a number of time constants--

$N = \frac{t}{RC}$ (where:
t is any given time in seconds
R is resistance in ohms
C is capacitance in farads
N is the number of time constants)

VII. Universal time constant chart (Transparency 2)

A. Horizontal axis--TC or time constants (either RC or L/R)

B. Vertical axis--Percentage of full voltage or full current

C. Rising curve A--Capacitor voltage during charge

D. Decaying curve B--

1. Capacitor voltage during discharge

2. Resistor voltage during charge

VIII. Exponential formulas and units of measurement for the voltage in an RC circuit during charge

A. Formula for voltage across a capacitor: $e_C = E_A\ (1 - \epsilon^{\frac{-t}{RC}})$

INFORMATION SHEET

B. Units of measurement for voltage across a capacitor:

1. e_C is instantaneous voltage across capacitor
2. E_A is source or applied voltage
3. R is resistance in ohms
4. C is capacitance in farads
5. ϵ is base of natural logarithms or 2.718...

C. Formula for voltage across a resistor: $e_R = E_A \epsilon^{\frac{-t}{RC}}$

D. Units of measurement for voltage across resistor:

1. e_R is instantaneous voltage across resistor
2. E_A is source or applied voltage
3. t is time in seconds
4. R is resistance in ohms
5. C is capacitance in farads
6. ϵ is base of natural logarithms or 2.718...

IX. Exponential formula and units of measurement for the charge current of an RC current

A. Formula:

$$i_c = \frac{E_A}{R} \epsilon \ {-t/RC}$$

B. Units of measurement:

1. i_c is instantaneous current in RC circuit during charge
2. E_A is source or applied voltage
3. t is time in seconds
4. R is resistance in ohms
5. C is capacitance in farads
6. ϵ is base of natural logarithms or 2.718...

INFORMATION SHEET

X. Exponential formula and units of measurement for the voltage across a resistor during discharge of an RC circuit

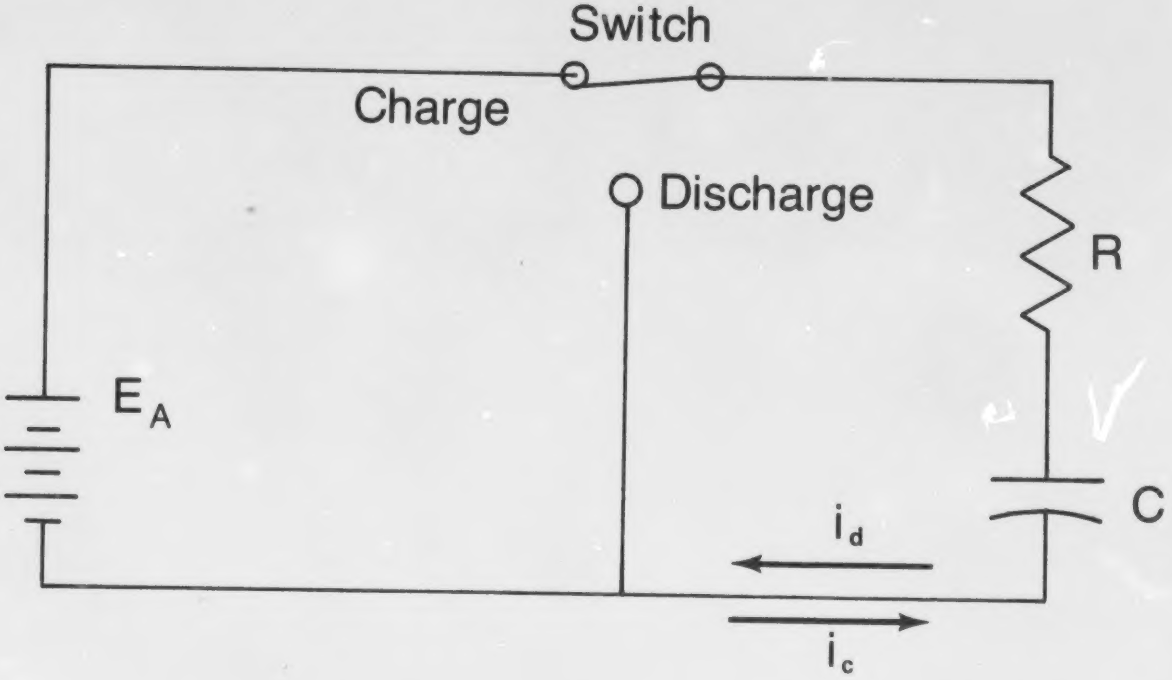
A. Formula:

$$e_R = e_C \epsilon \frac{-t}{RC}$$

B. Units of measurement:

1. e_R is instantaneous voltage across resistor during discharge
2. e_C is voltage across capacitor
3. R is resistance in ohms
4. C is capacitance in farads
5. t is time in seconds
6. ϵ is base of natural logarithms or 2.718...

RC Time Constant Circuit

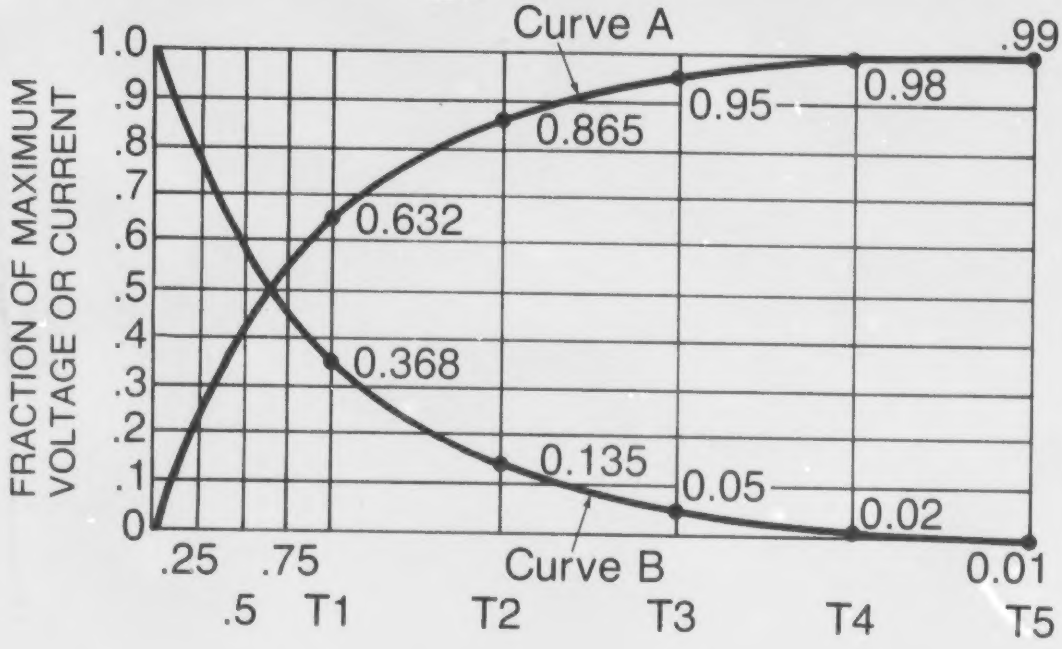

Switch
Charge
Discharge
R
E_A
C
i_d
i_c

Universal Time Constant Chart for RC and RL Circuits

Capacitor voltage on charge.

Inductor current on growth.

Resistor voltage on growth of inductor current.



Time Constant: RC or $\frac{L}{R}$

Capacitor voltage on discharge. Capacitor current on charge. Inductor voltage on growth of current. Inductor current on decay. Resistor voltage on charge.

RC TIME CONSTANTS
UNIT VI

ASSIGNMENT SHEET #1–REVIEW SERIES RC AND RL CIRCUIT CHARACTERISTICS

1. Match the terms on the right with the phrases on the left.

______a. Purely resistive circuit	1. Capacitor only
______b. Purely inductive circuit	2. Inductor and resistor
______c. Purely capacitive circuit	3. Resistor only
______d. RL circuit	4. Resistor and capacitor
______e. RC circuit	5. Inductor only

2. Select true statements concerning a series RC circuit being charged by placing an "X" in the appropriate blanks.

   ______a. Current takes 5TC to reach maximum value

   ______b. Maximum current rises immediately

   ______c. Voltage across the resistor begins to increase

   ______d. Voltage across resistor begins decreasing

   ______e. Capacitor voltage rises immediately to source value

   ______f. Capacitor voltage takes 5TC to reach applied voltage value

3. To reach fully charged state during charge, a capacitor takes________time constants

4. Select true statements which complete this sentence: After five time constants, during charge:

   ______a. Capacitor voltage is zero

   ______b. Capacitor voltage is at its maximum

   ______c. Current is at zero

   ______d. Current is at maximum

5. Select true statements concerning an RC circuit when it starts to discharge by placing an "X" in the appropriate blanks.

   ______a. Total current immediately drops to zero

   ______b. Current immediately is at its maximum value

   ______c. Current begins to rise slowly

ASSIGNMENT SHEET #1

______d. Capacitor voltage begins to decrease

______e. Voltage drop across resistor begins to increase to maximum

______f. Voltage drop across resistor begins to approach zero

6. Select true statements concerning a capacitor in an RC circuit when it is fully discharged by placing an "X" in the appropriate blanks.

______a. e_C is at maximum

______b. e_C is at zero

______c. e_R is at zero

______d. e_R is at maximum

______e. i is at maximum

______f. i is at zero

RC TIME CONSTANTS
UNIT VI

ASSIGNMENT SHEET #2--COMPUTE RC TIME CONSTANTS

1. Write the formula for computing one time constant in an RC circuit.

2. Match the curves on the right to the correct descriptions.

_____a. Voltage of capacitor during charge	1. Universal chart rising curve
_____b. Voltage of capacitor during discharge	
_____c. Current during charge	2. Universal chart falling curve
_____d. Current during discharge	
_____e. Voltage of resistor during charge	
_____f. Voltage of resistor during discharge	

3. If E_A = 200 volts and R = 50 ohms, compute (use the universal chart) the following for an RC circuit during charge

   a. Maximum current________________________________

   b. Current after two time constants________________________________

   c. e_C after three time constants________________________________

   d. e_R after three time constants________________________________

4. Using the same values for E_A and for R as in problem 3, compute the following for an RC circuit during discharge

   (NOTE: Use universal chart.)

   a. Current after four time constants________________________________

   b. e_C after two time constants________________________________

   c. e_R after two time constants________________________________

5. A circuit has the following values of R and C; compute one time constant.

   a. R = 1 Megohm, C = 1 μ f TC = _____

   b. R = 1 Kilohm, C = 20000μf TC = _____

   c. R = 1500 ohms, C = 200 pf TC = _____

   d. R = 47 kilohm, C = 30 μ f TC = _____

ASSIGNMENT SHEET #2

6. Use the exponential formulas to solve for the following when E_A is 200V, R is 1 megohm, C is 2 microfarads, and t is 2.8 seconds.

   a. i_C (current during charge) = _______

   b. e_C during charge = _______

   c. e_R during charge = _______

   d. 2.8 seconds represents_______time constants

RC TIME CONSTANTS
UNIT VI

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

1. a. 3   c. 1   e. 4
   b. 5   d. 2

2. b, d, f

3. Five (or more)

4. b, c

5. b, d, f

6. b, c, f

Assignment Sheet #2

1. T or TC = RC

2. a. 1   d. 1
   b. 2   e. 2
   c. 2   f. 1

3. a. 4 amperes
   b. 0.54 amperes
   c. 190 volts
   d. 10 volts

4. a. .08 amperes
   b. 27 volts
   c. 27 volts

5. a. 1 second
   b. 20 seconds
   c. 300×10^{-9} or 300 nanoseconds or .3 microseconds
   d. 1.41 seconds

6. a. 49.3 microamperes
   b. 150.68 volts
   c. 49.32 volts
   d. 1.4 time constants

RC TIME CONSTANTS
UNIT VI

JOB SHEET #1--DETERMINE TIME CONSTANTS OF RC CIRCUITS

I. Tools and materials

A. DC power supply, 0-20V

B. Electronic voltmeter

C. R_1 - Resistor, 100 k-ohm, 1 watt

D. R_2 - Resistor, 470 k-ohm, 1 watt

E. R_3 - Resistor, 1 M-ohm, 1 watt

F. R_4 - Resistor, 2.2 M-ohm, 1 watt

G. C_1 and C_2 - Electrolytic capacitor, 10 μf, over 20VDC

H. S_1 Switch, DPDT

I. S_2, Switch, PBNO

J. Stopwatch (or watch with second hand)

II. Procedure

A. Connect the DC power supply, electronic voltmeter, switches, resistors R_1 and R_2, and Capacitor C_1 as shown in Figure 1; let R_1 and R_2 be R_Y, and C_1 be C and do not turn on the power supply at this time

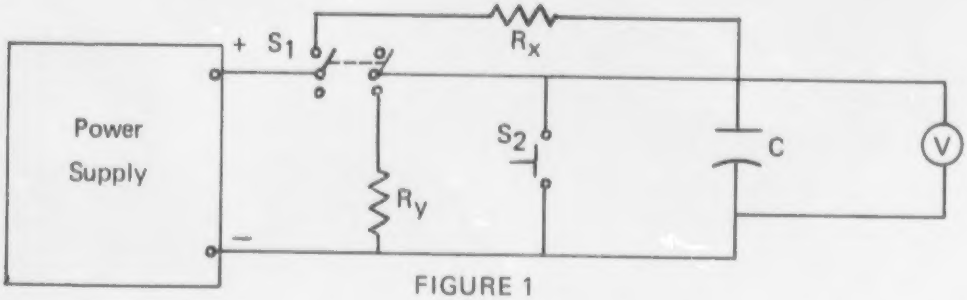


FIGURE 1

B. Calculate the time constant for the charging circuit of Figure 1 and enter in Table 1

(NOTE: Switch S_1 will be in the up position.)

JOB SHEET #1

C. Calculate the total time (5 time constants) for the capacitor to be fully charged and enter in Table 1

R-C VALUES				CHARGE			DISCHARGE		
				CALCULATED		MEASURED	CALCULATED		MEASURED
	Rx	Ry	C	1-TC	5-TC	Total Time	1-TC	5-TC	Total Time
1.	R_1	R_2	C_1						
2.	R_3	R_4	C_1						
3.	R_4	R_2	C_1 C_2 Series						
4.	R_3	R_1	C_1 C_2 Parallel						

TABLE 1

D. Calculate the time constant for the discharge circuit (S_1 will be in the down position) and enter in Table 1

E. Calculate the total time (5 time constants) for the capacitor to be fully discharged and enter in Table 1

F. Turn the power supply on and with S_1 in the up position, adjust for 15 volts as indicated by the voltmeter when the capacitor is fully charged

G. Flip S_1 to the down position to isolate the charging source

H. Close S_2 to discharge the capacitor, then release it

I. Start the stopwatch at the same time S_1 is placed in the up position to measure the time required for capacitor C_1 to charge to 15 volts, and record in Table 1

J. Start the stopwatch at the same time S_1 is placed in the down position to measure the time required for capacitor C_1 to completely discharge, and enter in Table 1

K. Rewire the circuit and repeat steps B through J for R-C values 2, 3, and 4 as shown in Table 1

L. Discuss with your instructor differences observed in calculated and measured values

RC TIME CONSTANTS
UNIT VI

JOB SHEET #2--CONSTRUCT A NEON BULB FLASHER

I. Tools and materials

- A. DC power supply, 0-100V (can use two 45V batteries)
- B. Two 2.2 M-ohm resistors
- C. Two 1 μf capacitors (at least 100v)
- D. Neon bulb

II. Procedure

- A. Connect the circuit as shown in Figure 1

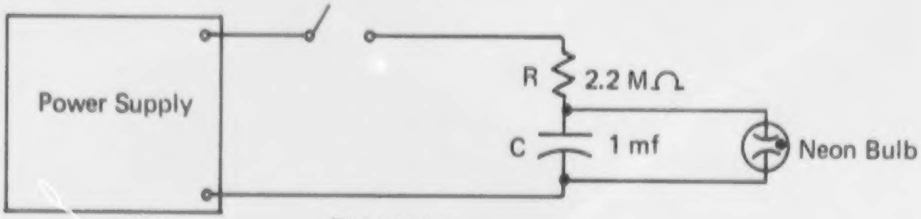


FIGURE 1

- B. Adjust the power supply to 100 volts
- C. Close the switch and observe the neon bulb
- D. Open the circuit and add a 2.2 M-ohm resistor in series to make a total of 4.4 megohms resistance
- E. Close the switch and observe the neon bulb
- F. Open the switch and remove one of the 2.2 megohm resistors
- G. Add a 1 μf capacitor in parallel with C in the circuit making 2 μf of capacitance
- H. Close the switch and observe the neon bulb
- I. Draw a sketch of the neon bulb lighting and going out using time as the horizontal axis and voltage as the vertical axis

  (NOTE: Assume 70 volts will cause the neon bulb to light and it will remain lit until the voltage drops to 40 volts.)
- J. Discuss the effect of increasing R and of increasing C

RC TIME CONSTANTS
UNIT VI

NAME______________________________

TEST

1. Match the terms on the right with the correct definitions.

_____a. A math expression with a fixed base and with varying exponents

_____b. A circuit producing an output proportional to the integral of one variable with respect to another

_____c. A circuit where the output voltage is proportional to the rate of change of the input voltage

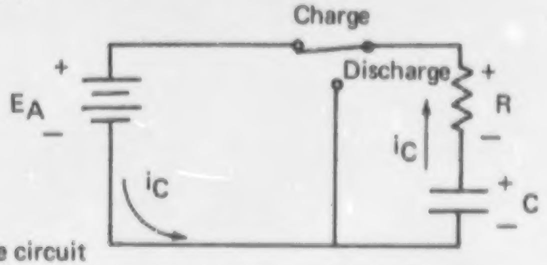
_____d. The base of the natural logarithms equal to 2.718...

_____e. Time required to complete 63.2 percent of the total time rise or decay

_____f. A circuit with resistance and capacitance

1. Time constant
2. Exponential function
3. RC circuit
4. Differentiating circuit
5. Integrating circuit
6. ϵ

2. Complete statements concerning charging an RC circuit by referring to the illustration below:



a. Charge circuit

1) Switch is in __________________ position

2) A resistor and capacitor are connected in series with a__________________ voltage source

b. At t_o (instant switch is closed)

1) i_C is maximum and equals__________________________

2) e_R is maximum and equals__________________________

3) e_C is__________________________

c. After about 5 time constants

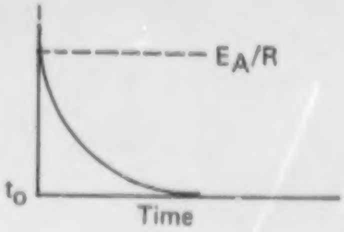
1) i_C ______________

2) e_C ______________

3) e_R ______________

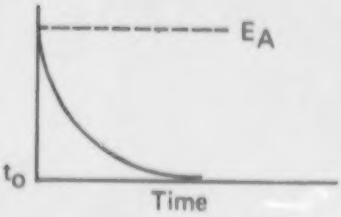
3. Match illustrations of waveshapes during the charge of an RC circuit with the values on the right which they reflect.

______ a.

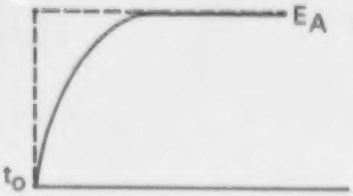


1. e_C
2. e_R
3. i_C and i_R

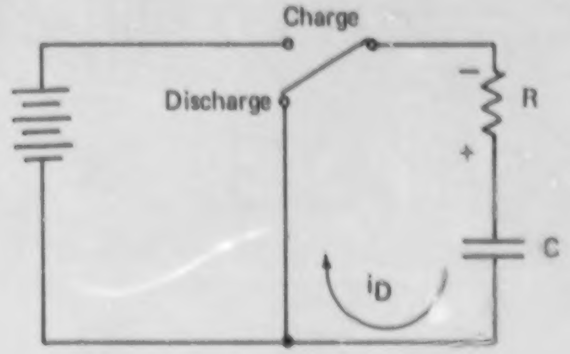
______ b.



______ c.



4. Complete statements concerning discharging an RC circuit by referring to the following illustration:



a. Discharge circuit

1) Switch is in ________________ position

2) e_C equals__________________

b. At t_o

1) i_d is maximum and equals_________________

2) e_R is maximum and equals________________

3) e_C is maximum and begins to_____________

c. After about 5 time constants

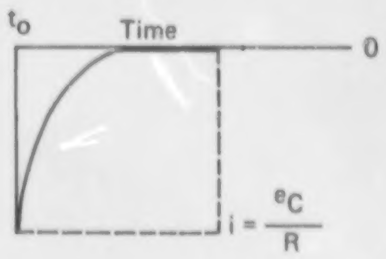
1) i_d approaches________exponentially from negative value

2) e_R approaches zero exponentially from __________value

3) e_C approaches_____________exponentially from positive value

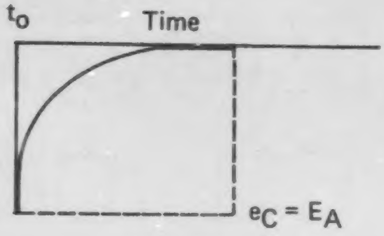
5. Match illustrations of waveshapes during discharge of an RC circuit with the values on the right which they reflect.

_____a.

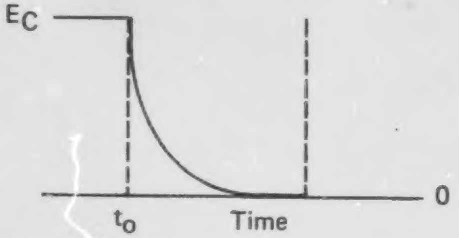


1. i_d
2. e_C
3. e_R

_____b.



_____c.



6. State the formulas for computing time constant.

   a. One time constant--

   b. A number of time constants--

7. List the units for measurement of the horizontal and vertical axes on a universal time constant chart.

   a. Horizontal--

   b. Vertical--

8. List units of measurement in the exponential formulas for voltage across a capacitor and voltage across a resistor in an RC circuit during charge.

   a. Formula for voltage across a capacitor:

$$e_C = E_A \left(1 - \epsilon^{\frac{-t}{RC}}\right)$$

      1) e_C is ______________________________

      2) E_A is ______________________________

      3) R is ______________________________

      4) C is ______________________________

      5) ϵ is ______________________________

b. Formula for voltage across a resistor: $e_R = E_A \epsilon^{\frac{-t}{RC}}$

1) e_R is ______________________________

2) E_A is ______________________________

3) t is ______________________________

4) R is ______________________________

5) C is ______________________________

6) ϵ is ______________________________

9. List units of measurement in the exponential formula for the charge current of an RC circuit when the formula is

$$i_c = \frac{E_A}{R} \epsilon^{-t/RC}$$

a. i_c is ______________________________

b. E_A is ______________________________

c. t is ______________________________

d. R is ______________________________

e. C is ______________________________

f. ϵ is ______________________________

10. List units of measurement in the exponential formula for the voltage across a resistor during discharge of an RC circuit when the formula is

$$e_R = e_C\, \epsilon^{\frac{-t}{RC}}$$

a. e_R is ______________________________

b. e_C is ______________________________

c. R is ______________________________

d. C is ______________________________

e. t is ______________________________

f. ϵ is ______________________________

11. Review series RC and RL circuit characteristics.
12. Compute RC time constants.
13. Demonstrate the ability to:
    a. Determine time constants of RC circuits.
    b. Construct a neon bulb flasher.

(NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

RC TIME CONSTANTS
UNIT VI

ANSWERS TO TEST

1. a. 2 d. 6
b. 5 e. 1
c. 4 f. 3

2. a. 1) On or charged
2) Direct-current

b. 1) E_A/R
2) E_A
3) Zero

c. 1) Decreases
2) Increases
3) Decreases

3. a. 3
b. 2
c. 1

4. a. 1) Discharge
2) E_A

b. 1) e_C/R
2) $i_d R$
3) decay

c. 1) Zero
2) Negative
3) Zero

5. a. 1
b. 3
c. 2

6. a. $T = RC$
b. $N = \frac{t}{RC}$

7. a. TC or time constants
b. Percentage of full voltage or full current

8. a. 1) Instantaneous voltage across capacitor
2) The source or applied voltage
3) Resistance in ohms
4) Capacitance in farads
5) Base of natural logarithms or 2.718...

b. 1) Instantaneous voltage across resistor
   2) Source or applied voltage
   3) Time in seconds
   4) Resistance in ohms
   5) Capacitance in farads
   6) Base of natural logarithms or 2.718...

9. a. Instantaneous current in RC circuit during charge
   b. Source or applied voltage
   c. Time in seconds
   d. Resistance in ohms
   e. Capacitance in farads
   f. Base of natural logarithms or 2.718...

10. a. Instantaneous voltage across resistor during discharge
    b. Voltage across capacitor
    c. Resistance in ohms
    d. Capacitance in farads
    e. Time in seconds
    f. Base of natural logarithms or 2.718...

11. Evaluated to the satisfaction of the instructor.

12. Evaluated to the satisfaction of the instructor.

13. Performance skills evaluated to the satisfaction of the instructor.

CAPACITIVE REACTANCE
UNIT VII

UNIT OBJECTIVE

After completion of this unit, the student should be able to compute capacitive reactance, determine phase relationships in RC circuits, and compute values of RC circuits. The student should also be able to show the effect of capacitive reactance in AC circuits and determine capacitive reactance and impedance in RC circuits. This knowledge will be evidenced by correctly performing the procedures outlined in the assignment and job sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms associated with capacitive reactance with their correct definitions.
2. Match symbols associated with capacitive reactance with their correct meanings.
3. State the formula for computing capacitive reactance.
4. List two factors that are inversely proportional to capacitive reactance.
5. Select true statements indicating the relationships between current and voltage in RC circuits.
6. Compute the applied voltage, impedance, and power factor of an RC circuit when given the resistive voltage, the capacitive voltage, and the current.
7. Distinguish between true power, apparent power, reactive power, and the power factor.
8. State the formula for computing the figure of merit, or Q, of a capacitor when series resistance is known.
9. Compute capacitive reactance.
10. Determine phase relationships in RC circuits.
11. Compute values of RC circuits.
12. Demonstrate the ability to:
    a. Show the effect of capacitive reactance in AC circuits.
    b. Determine capacitive reactance and impedance in RC circuits.

CAPACITIVE REACTANCE
UNIT VII

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information, assignment, and job sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information and assignment sheets.

VI. Demonstrate and discuss the procedures outlined in the job sheets.

VII. Demonstrate oscilloscope waveshapes, if possible, to show phase relationships.

VIII. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

- A. Objective sheet
- B. Information sheet
- C. Transparency masters
    1. TM 1--Voltage Relationships RC Circuit
    2. TM 2--Impedance Relationships RC Circuit
    3. TM 3--Power Relationships RC Circuit
- D. Assignment sheets
    1. Assignment Sheet #1--Compute Capacitive Reactance
    2. Assignment Sheet #2--Determine Phase Relationships in RC Circuits
    3. Assignment Sheet #3--Compute Values of RC Circuits
- E. Answers to assignment sheets

F. Job sheets

  1. Job Sheet #1--Show the Effect of Capacitive Reactance in AC Circuits

  2. Job Sheet #2--Determine Capacitive Reactance and Impedance in RC Circuits

G. Test

H. Answers to test

II. References:

A. Bernard Grob. *Basic Electronics.* New York: McGraw-Hill, 1977.

B. *Basic Electricity/Electronics.* Natchitoches, LA: Louisiana Department of Vocational Education, 1979.

C. Robertson, L. P. *Instrumentation and Measurements Handbook.* Albuquerque, NM: Sandia Laboratories, 1971.

D. *IEEE Standard Dictionary of Electrical and Electronic Terms.* New York: John Wiley & Sons, 1972.

CAPACITIVE REACTANCE
UNIT VII

INFORMATION SHEET

I. Terms and definitions

A. Resistance--Opposition to current resulting in energy dissipation

B. Reactance--Opposition to current not resulting in energy dissipation caused by voltage or current charges

C. Impedance--Opposition to current including both resistance and reactance

D. Capacitive reactance--Circuit opposition caused by capacitance

E. Power--The rate of energy consumption in a circuit (true power)

F. Reactive power--The product of reactive voltage and amperes

G. Apparent power--The product of volts and amperes in an AC circuit

H. Power factor--The ratio of true power to apparent power (volt-amperes) in an AC circuit

I. Phase angle--The number of degrees that the current leads or lags the voltage in an AC circuit

(NOTE: The phase angle may also be expressed in radians.)

J. Angular velocity--The rate of change of cyclical motion

II. Symbols and meanings

A. X--Reactance in ohms

B. X_C--Capacitive reactance in ohms

C. f--Frequency in hertz

D. C--Capacitance in farads

E. R--Resistance in ohms

F. ω--Angular velocity in radians per second (equal to $2\pi f$)

G. 2π--Radians in one cycle (equal to approximately 6.28)

H. θ--Phase angle in degrees or radians

I. PF--Power factor

INFORMATION SHEET

III. Formula for computing capacitive reactance

$$X_C = \frac{1}{\omega C} \text{ or } \frac{1}{2\pi fC} \text{ or } \frac{.159}{fC}$$

where X_C is capacitive reactance in ohms
ω is angular velocity in radians per second
C is capacitance in farads
f is frequency in Hertz

IV. Factors that are inversely proportional to capacitive reactance

A. Rate of change of voltage (frequency)

B. Amount of capacitance

V. Relationships between current and voltage in RC circuits

A. Current leads voltage by 90° in a purely capacitive circuit

B. Current and voltage are in phase in a purely resistive circuit

C. Current leads voltage between 0° and 90° depending upon relative amounts of R and C present in circuit and frequency of applied voltage or current (angular velocity)

VI. Computing applied voltage, impedance, and the power factor in a series RC circuit

A. Current in series circuit is same throughout and used as reference

B. Voltage across resistor (E_R) is in phase with current

C. Voltage across capacitor (E_C) lags the current by 90°

D. Applied voltage (E_A) is vector sum of the two out-of-phase voltages and equals $E_A = \sqrt{(E_R)^2 + (E_C)^2}$ (Transparency 1)

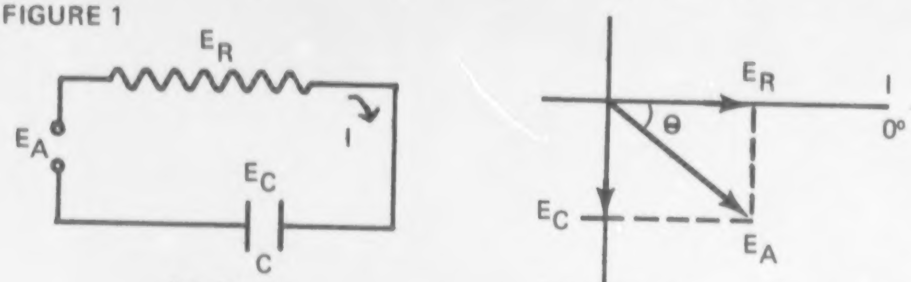
E. Dividing each term of the equation in D by current gives impedance formula (Transparency 2)

$$Z = \sqrt{(R)^2 + (X_C)^2}$$

INFORMATION SHEET

F. Power factor, θ, is the angle whose cosine equals E_R/E_A (Figure 1)

FIGURE 1



RC Circuit

RC Phase Relationships

VII. Power in capacitive circuits

A. True power--The actual power consumed by resistance and is measured in watts

1. $P_T = I^2R$ or E_RI_R
2. $P_T = EI(PF)$ or $EI \cos \theta$

B. Apparent power--The power that appears to be used and is measured in volt-amperes (Transparency 3)

1. $P_A = EI$
2. $P_A = I^2Z$
3. $P_A = E^2/Z$

C. Reactive power--The power that appears to be used by the reactive components

(NOTE: Capacitors use no power or energy; they take from the circuit to create electrostatic fields but return to the circuit when the voltage direction reverses.)

1. $P_X = I^2X$
2. $P_X = E_XI_X$
3. $P_X = EI \sin \theta$

D. Power factor--The ratio of true power to apparent power (Transparency 3)

1. $PF = P_T/P_A$
2. $PF = E_X/E_A$

INFORMATION SHEET

3. $PF = R/Z$

4. $PF = \cos\theta$

III. Figure of merit, or Q, of capacitors

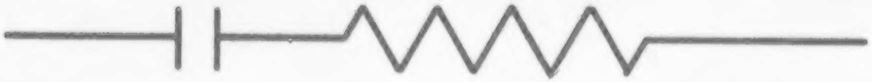
A. The quality factor or figure of merit of a component is a measure of that component's energy storing ability

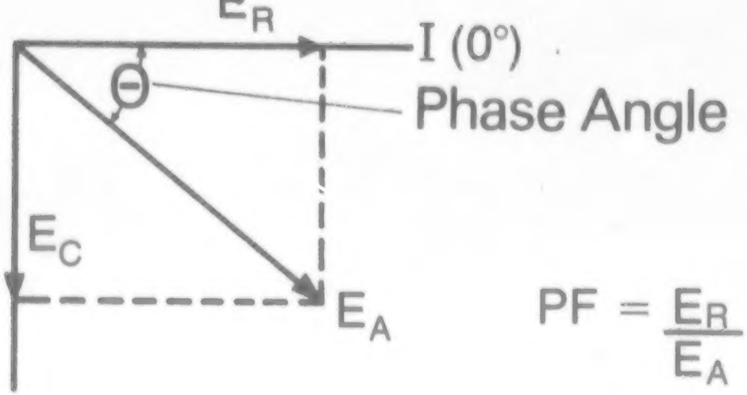
B. For a capacitor and resistance in series:

$$Q = \frac{X_C}{R_s}$$

where X_C is capacitive reactance in ohms and R_s is series resistance in ohms

Voltage Relationships RC Circuit




E_R
I (0°)
Θ
Phase Angle
E_C
E_A

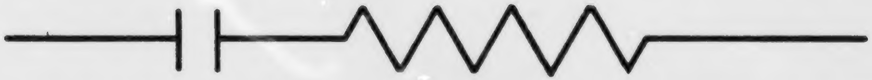
$$PF = \frac{E_R}{E_A}$$

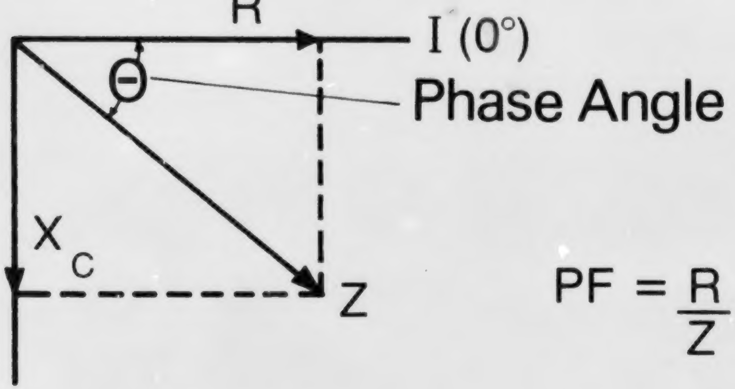
$$E_A = I \times Z = \sqrt{(E_A)^2 + (E_R)^2}$$

TM 1

BE - 219-D

Impedance Relationships RC Circuit

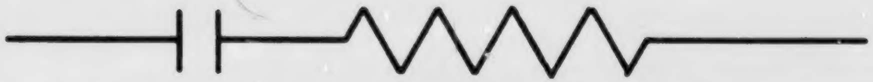


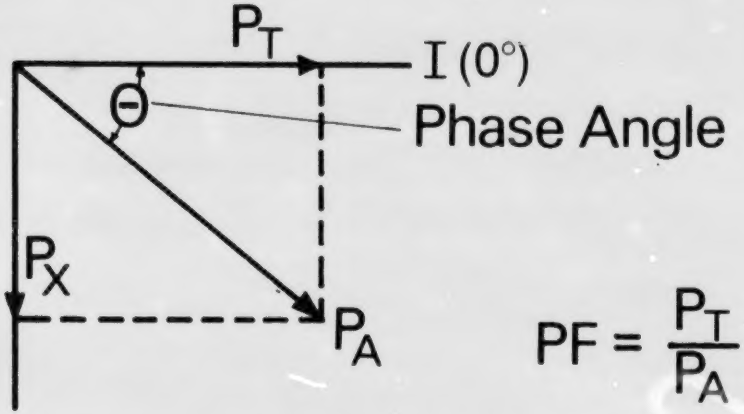

R
I (0°)
Θ
Phase Angle
X_C
Z

$$PF = \frac{R}{Z}$$

$$Z = \sqrt{R^2 + X_C^2}$$

Power Relationships RC Circuit




P_T
I (0°)
Θ
Phase Angle
P_X
P_A

$$PF = \frac{P_T}{P_A}$$

$$P_A = E_A \times I$$

CAPACITIVE REACTANCE
UNIT VII

ASSIGNMENT SHEET #1--COMPUTE CAPACITIVE REACTANCE

Directions: Review the formula for computing capacitive reactance and compute X_C from the C and f values given below:

1. Write the formula for computing capacitive reactance.

   $X_C =$

2. Select the units of measure capacitive reactance is expressed in:

   _____a. Farads

   _____b. Henries

   _____c. Ohms

   _____d. Radians

3. If the frequency of the applied voltage to an RC circuit is increased, the capacitive reactance will (increase) (decrease).

4. If the capacitance is increased in a given RC circuit, the capacitive reactance will (increase) (decrease).

5. The angular velocity is decreased by decreasing:

   _____a. Frequency

   _____b. Phase angle

   _____c. Power factor

   _____d. Capacitance

6. Compute X_C for the following values of C and f:

   _____a. C = 10,000 μf, f = 10 Hz

   _____b. C = 10 μf, f = 60 Hz

7. At what frequency would a 0.05 microfarad capacitor have 40 ohms of capacitive reactance?

CAPACITIVE REACTANCE
UNIT VII

ASSIGNMENT SHEET #2--DETERMINE PHASE RELATIONSHIPS IN RC CIRCUITS

Directions: Using the chart and diagrams below, determine the following:

1. Which curve from the chart in Figure 1 represents AC current in a capacitive circuit?
2. Which curve from the chart in Figure 1 represents AC voltage in a capacitive circuit?

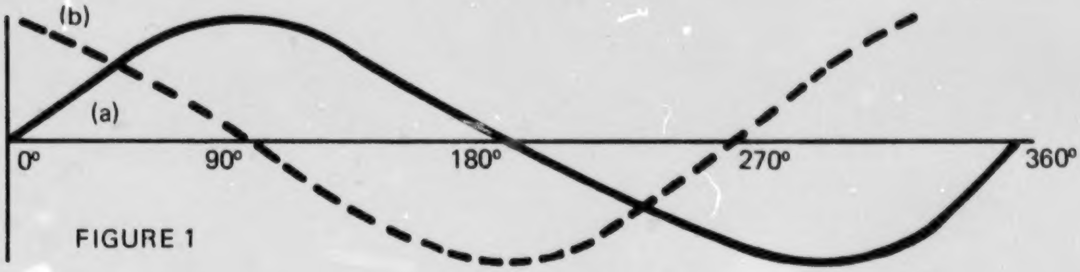
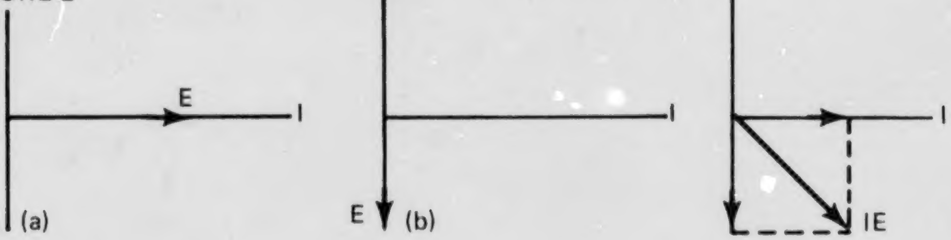


FIGURE 1

3. Which diagram in Figure 2 represents a purely capacitive AC circuit?
4. Which diagram in Figure 2 represents a purely resistive AC circuit?
5. Which diagram in Figure 2 represents a circuit with R and C?

FIGURE 2



6. Explain what is meant when a circuit has a power factor of 1.

CAPACITIVE REACTANCE
UNIT VII

ASSIGNMENT SHEET #3--COMPUTE VALUES OF RC CIRCUITS

1. Select true statements concerning RC circuits by placing an "X" in the appropriate blanks.

    ______ a. The current in a series RC circuit is the same in the resistor as in the capacitor at all times when AC voltage is applied.

    ______ b. The voltage in a series RC circuit is the same across the resistor as across the capacitor at all times when AC is applied.

    ______ c. Current leads the voltage by 90 degrees in a purely capacitive circuit.

    ______ d. Current lags the voltage by 90 degrees in a purely capacitive circuit.

    ______ e. Current is in phase with voltage in a purely resistive circuit.

    ______ f. Voltage lags the current by 90 degrees in a purely capacitive circuit.

    ______ g. Voltage across the resistor is always in phase with the applied voltage in an RC circuit.

    ______ h. If 100 volts is applied to a circuit having 50 ohms of resistance and 50 ohms of capacitive reactance, there will be 50 volts drop across the resistor and 50 volts drop across the capacitor.

2. If there are 40 ohms of resistance in series with 40 ohms of capacitive reactance, the circuit impedance, Z, equals ______________________ ohms.

3. If there is a 40 volt drop across the resistor and a 30 volt drop across the capacitor in an RC circuit, the applied voltage is ________________ volts and the phase angle is ________________ degrees.

4. Solve the following circuit for the indicated values.

    a. X_C = ______

    b. Z = ______

    c. I = ______

    d. E_R = ______

    e. E_C = ______

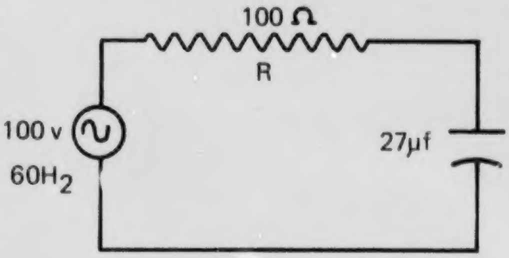
    f. θ = ______

    g. PF = ______

    h. P_A = ______

    i. P_X = ______

    j. P_T = ______



CAPACITIVE REACTANCE
UNIT VII

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

1. $X_C = \frac{1}{2\pi fC}$ or $\frac{1}{\omega C}$ or $\frac{.159}{fC}$
2. c
3. Decrease
4. Decrease
5. a
6. a. 1.59 ohms
   b. 265 ohms
7. 79,500 Hertz

Assignment Sheet #2

1. a
2. b
3. b
4. a
5. c
6. A power factor of 1 means that the circuit is a resistive circuit

Asisgnment Sheet #3

1. a, c, e, f
2. 56.6 ohms
3. 50 volts, 36.9° (arc cos 40/50)
4. a. 98.1 ohms
   b. 140 ohms
   c. 714 milliamps
   d. 71.4 volts
   e. 70.0 volts
   f. 45.6 degrees
   g. .699
   h. 71.4 volt-amperes
   i. 50 vars
   j. 51 watts

CAPACITIVE REACTANCE
UNIT VII

JOB SHEET #1--SHOW THE EFFECT OF CAPACITIVE REACTANCE IN AC CIRCUITS

I. Tools and materials

A. Two AC capacitors - 8 μf and 1 μf, 115 VAC

B. One 15W, 120V light bulb and holder

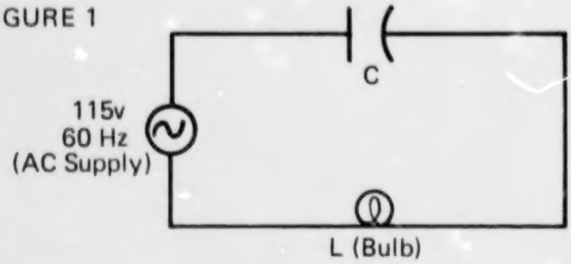
C. Multimeter

D. AC power

II. Procedure

A. Connect the circuit as shown using the 8 μf capacitor (Figure 1)

FIGURE 1



B. Turn on the AC and observe the brightness of the bulb

C. Measure and record E_A, E_C, and E_L (voltage across bulb or load)

D. Compute $(E_C)^2$ plus $(E_L)^2$, obtain square root, then compare with measured value of E_A

E. Substitute the 1 μf capacitor for the 8 μf capacitor, then repeat steps B, C, and D

F. Discuss the relative amounts of capacitive reactance of the 8 μf and 1 μf capacitor; that is, which has the most opposition to the flow of current

G. Discuss the differences observed between measured and calculated values of E_A

CAPACITIVE REACTANCE
UNIT VII

JOB SHEET #2--DETERMINE CAPACITIVE REACTANCE AND IMPEDANCE IN RC CIRCUITS

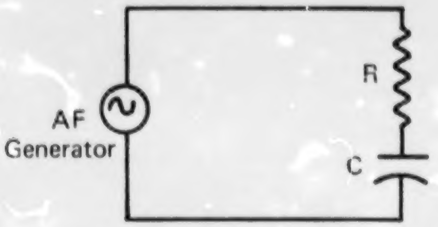
I. Tools and materials

- A. One af generator
- B. One capacitor - .3 μf
- C. One resistor, 1000 ohm, 1-watt
- D. Multimeter
- E. Graph paper and protractor

II. Procedure

- A. Connect the circuit shown in the following schematic (Figure 1)

FIGURE 1



- B. Set the af generator to a frequency of 150 Hz and adjust the output to one volt, then measure E_R and E_C and record in the data table
- C. Set the af generator to the next frequency listed in the data table; adjust the output to one volt, then measure and record E_R and E_C
- D. Repeat Step C for each listed frequency

			I	Z	X_C	X_C	Z	θ	θ	PF
Frequency	E_R	E_C	E_R/R	E_A/I	$1/\omega C$	E_C/I	Graph	Graph	Arc cos E_R/E_A	Cos θ
150 Hz										
250 Hz										
450 Hz										
900 Hz										
1100 Hz										

Data Table

JOB SHEET #2

E. Compute I (E_R/10,000) for each frequency and enter into table

F. Compute Z(E_A/I) for each frequency and enter

G. Compute X_C by using the formula 1/C for each frequency

H. Compute X_C (E_C/I), enter into table, and compare results with Step G

I. Using X_C of Step H, and 10,000 for R, draw a graph showing the vector relationships, then measure the value of Z on the graph

J. Compare the results of Step I with Step F

K. Measure the phase angle, θ, on the graph and enter

L. Compute the phase angle, θ, by obtaining the angle whose cosine is E_R/E_A

M. Compute and enter the power factor

N. Calculate the frequency necessary to have X_C equal to 10,000 ohms

O. Set the af generator to this frequency and enter all information called for into the data table

P. Analyze and discuss your results with your instructor

CAPACITIVE REACTANCE
UNIT VII

NAME _______________________

TEST

1. Match the terms on the right with their correct definitions.

_____a. The number of degrees that the current leads or lags the voltage in an AC circuit

_____b. The product of reactive voltage and amperes

_____c. Opposition to current including both resistance and reactance

_____d. Opposition to current resulting in energy dissipation

_____e. Circuit opposition caused by capacitance

_____f. The product of volts and amperes in an AC circuit

_____g. The rate of change of cyclical motion

_____h. Opposition to current not resulting in energy dissipation caused by voltage or current charges

_____i. The rate of energy consumption in a circuit

_____j. The ratio of true power to apparent power in an AC circuit

1. Resistance
2. Reactance
3. Impedance
4. Capacitive reactance
5. Power
6. Reactive power
7. Apparent power
8. Power factor
9. Phase angle
10. Angular velocity

2. Match the symbols on the right with their correct meanings.

_____a. Angular velocity in radians per second

_____b. Reactance in ohms

_____c. Capacitance in farads

_____d. Phase angle in degrees or radians

_____e. Resistance in ohms

_____f. Frequency in hertz

1. X
2. X_C
3. f
4. C
5. R
6. ω
7. 2π
8. θ
9. PF

_____g. Power factor

_____h. Capacitive reactance in ohms

_____i. Radians in one cycle

3. State a formula for computing capacitive reactance.

4. List two factors that are inversely proportional to capacitive reactance.

   a. ____

   b. ____

5. Select true statements indicating the voltage and current relationships in RC circuits by placing an "X" in the appropriate blanks.

_____a. Current leads voltage by 90° in a purely capacitive circuit

_____b. Current lags voltage by 90° in a purely capacitive circuit

_____c. Current and voltage are in phase in a purely capacitive circuit

_____d. Current and voltage are in phase in a purely resistive circuit

_____e. Current leads voltage between 0° and 90° depending upon relative amounts of R and C present in circuit and frequency of applied voltage or current

_____f. Current lags voltage between 0° and 90° in a circuit containing both resistance and capacitance

6. In an RC circuit the voltage across the resistor is 120 volts, the voltage across the capacitor is 50 volts, and the current is .013 amperes. Compute the following:

   a. The AC voltage applied in the above circuit is_______________volts.

   b. The impedance of the above circuit is_______________hms.

   c. The power factor of the above circuit is_______________.

7. Distinguish between true power, apparent power, reactive power, and the power factor by placing a "t" next to formulas or descriptions of true power, an "a" next to formulas or descriptions for apparent power, an "r" next to formulas or descriptions of reactive power, or an "f" next to formulas or descriptions of the power factor.

_____a. The power that appears to be used by the reactive components

_____b. EI (PF) or EI cos θ

_____c. I^2X

______d. I^2R or E_RI_R

______e. The power that appears to be used and is measured in volt-amperes

______f. The actual power consumed by resistance and is measured in watts

______g. E_X/E_A

______h. E^2/Z

______i. I^2Z

______j. The ratio of true power to apparent power

8. State the formula for computing the figure of merit, or Q, of a capacitor when the series resistance is known.

9. Compute capacitive reactance.

10. Determine phase relationships in RC circuits.

11. Compute values of RC circuits.

12. Demonstrate the ability to:

    a. Show the effect of capacitive reactance in AC circuits.

    b. Determine capacitive reactance and impedance in AC circuits.

    (NOTE: If these activities have not been completed prior to the test, ask your instructor when they should be completed.)

CAPACITIVE REACTANCE
UNIT VII

ANSWERS TO TEST

1.
   a. 9
   b. 6
   c. 3
   d. 1
   e. 4
   f. 7
   g. 10
   h. 2
   i. 5
   j. 8

2.
   a. 6
   b. 1
   c. 4
   d. 8
   e. 5
   f. 3
   g. 9
   h. 2
   i. 7

3. $X_C = \frac{1}{\omega C}$ or $\frac{1}{2\pi fC}$ or $\frac{.159}{fC}$

4.
   a. Rate of change of voltage
   b. Amount of capacitance

5. a, d, e

6.
   a. 130 volts
   b. 10,000 or 10K ohms
   c. .9999 or 1 (cos 120/130)

7.
   a. r
   b. t
   c. r
   d. t
   e. a
   f. t
   g. f
   h. a
   i. a
   j. f

8. $Q = \frac{X_C}{R_s}$

9. Evaluated to the satisfaction of the instructor.

10. Evaluated to the satisfaction of the instructor.

11. Evaluated to the satisfaction of the instructor.

12. Performance skills evaluated to the satisfaction of the instructor.

SERIES RCL CIRCUITS
UNIT VIII

UNIT OBJECTIVE

After completion of this unit, the student should be able to state the formulas for computing impedance, applied voltage, resonant frequency, and bandwidth in relation to RCL circuits. The student should also be able to solve problems of reactance, impedance, and parameters of resonant circuits, and demonstrate the ability to determine resonance in a series RCL circuit. This knowledge will be evidenced by correctly performing the procedures outlined on the assignment and job sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms associated with series RCL circuits with the correct definitions.
2. Match the reactance in a series RCL circuit with the circuit condition.
3. Select true statements regarding impedance in series RCL circuits.
4. State the formula for computing impedance in a series RCL circuit.
5. Match voltages with their relationship to the current in a series RCL circuit.
6. State the formula for computing the applied voltage in terms of voltage drops.
7. List conditions existing in a resonant series RCL circuit.
8. State the formula for computing resonant frequency.
9. Differentiate between resonant frequency variation with respect to capacitance and inductance in a tuned series RCL circuit.
10. Select true statements regarding the Q of a series tuned circuit.
11. State the formula for bandwidth.
12. Solve for reactance.
13. Solve for impedance.
14. Solve for parameters of resonant circuits.
15. Demonstrate the ability to determine resonance in a series RCL circuit.

SERIES RCL CIRCUITS
UNIT VIII

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information, assignment, and job sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information and assignment sheets.

VI. Demonstrate and discuss the procedures outlined in the job sheet.

VII. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:
   A. Objective sheet
   B. Information sheet
   C. Transparency masters
      1. TM 1--Impedance Relationship in a Series RCL Circuit
      2. TM 2--Voltage Relationship in a Series RCL Circuit
      3. TM 3--Resonance Relationship in a Series RCL Circuit
      4. TM 4--Typical Resonant Curves
   D. Assignment sheets
      1. Assignment Sheet #1--Solve for Reactance
      2. Assignment Sheet #2--Solve for Impedance
      3. Assignment Sheet #3--Solve for Parameters of Resonant Circuits
   E. Answers to assignment sheets
   F. Job Sheet #1--Determine Resonance in a Series RCL Circuit

G. Test

H. Answers to test

II. References:

A. Grob, Bernard. *Basic Electronics.* New York: McGraw-Hill, 1977.

B. *Fundamentals of Electricity.* Fort Sill, OK: U.S. Army Field Artillery School, 1975.

C. Tinnell, R. W. *Electricity.* Albany, NY: Delmar Publishers, 1975.

D. Robertson, L. P. *Instrumentation and Measurements Handbook.* Albuquerque, NM: Sandia Laboratories, 1971.

SERIES RCL CIRCUITS
UNIT VIII

INFORMATION SHEET

I. Terms and definitions

   A. Series RCL circuit--A circuit containing resistance, inductance, and capacitance through which a common current flows

   (NOTE: There may not be a resistor in the circuit but resistance is always present in the wire.)

   B. Reactance--The opposition to current flow by a capacitor or an inductor

   C. Impedance--The total opposition to the flow of current

   (NOTE: In an RCL circuit, this consists of resistance, inductive reactance, and capacitive reactance.)

   D. Resonance--Condition of a circuit where the inductive and capacitive effects cancel each other

   E. Bandwidth--Section of frequency spectrum passing through a series resonant circuit; it is abbreviated by BW

II. Reactance in series RCL circuits

   A. Total reactance is combination of inductive reactance, X_L, and capacitive reactance, X_C

   B. Total reactance, X_T, equals $X_L - X_C$

   C. When X_T is positive, i.e., X_L is greater than X_C, the circuit is inductive

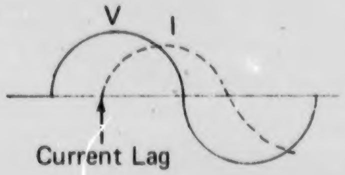
   D. When X_T is negative, i.e., X_L is less than X_C, the circuit is capacitive

   E. When X_T is zero, i.e., X_L equals X_C, the circuit is resistive (said to be resonant)

III. Impedance in series RCL circuits (Transparencies 1 and 2)

   A. Pure inductance causes current to lag the voltage by 90 degrees (Figure 1)

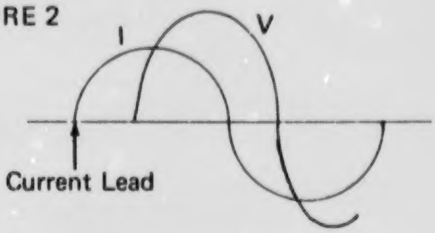
FIGURE 1



INFORMATION SHEET

B. Pure capacitance causes current to lead the voltage by 90 degrees (Figure 2)

FIGURE 2



C. Leading voltages and lagging voltages tend to neutralize each other

(NOTE: $E_X = E_L - E_C$.)

IV. Formula for impedance in series RCL circuits

Impedance, Z, equals $\sqrt{R^2 + (X_L - X_C)^2}$

V. Voltages and current in series RCL circuits (Transparency 2)

A. Current is common in all components and is used as the reference

B. Voltage across resistance, V_R, is in phase with the current

C. Voltage across inductor, V_L, leads the current by 90 degrees

D. Voltage across capacitor, V_C, lags the current by 90 degrees

E. Reactive voltage, V_X, is sum of inductive and capacitive voltages $(V_L - V_C)$

VI. Formula for applied voltage in series RCL circuits in terms of voltage drops

Applied voltage, E_A, equals $\sqrt{V^2{}_R + (V_L - V_C)^2}$

VII. Resonance in series RCL circuits (Transparency 3)

A. Resonance occurs when inductive effect equals capacitive effect

B. Impedance is at minimum value and equal to R

C. Current is maximum, limited only by the resistance, R

D. Phase angle between voltage and current is zero

E. V_L and V_C are equal and are larger than E_A

INFORMATION SHEET

VIII. Formula for resonant frequency

Resonant frequency, f_r, equals $\frac{1}{2\pi\sqrt{LC}} = \frac{1}{6.28\sqrt{LC}} = \frac{.159}{\sqrt{LC}}$

IX. Tuned series RCL circuits

A. Increasing inductance or capacitance decreases the resonant frequency

B. Decreasing inductance or capacitance increases the resonant frequency

C. Only currents close to the resonant frequency can pass without much opposition

D. Tuned RCL circuits used to pass currents close to the resonant frequency are called filters

X. The Q of a series tuned circuit

A. Q is a measure of the selectivity of the circuit

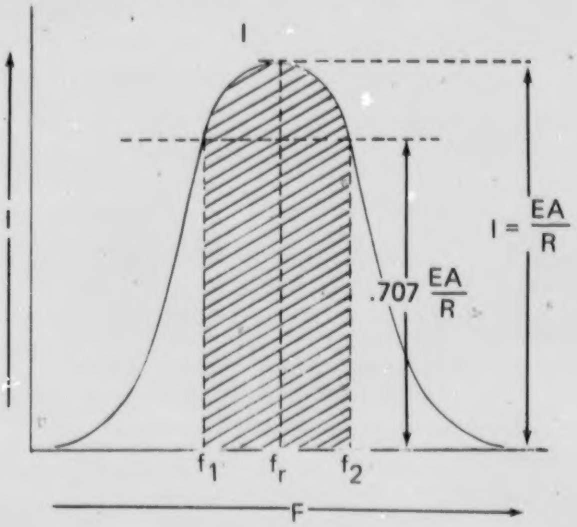
B. Q varies inversely with resistance (Transparency 4)

C. The formula for Q is X_L/R

(NOTE: Since at resonance $X_L = X_C$, either value may be used in the formula for Q.)

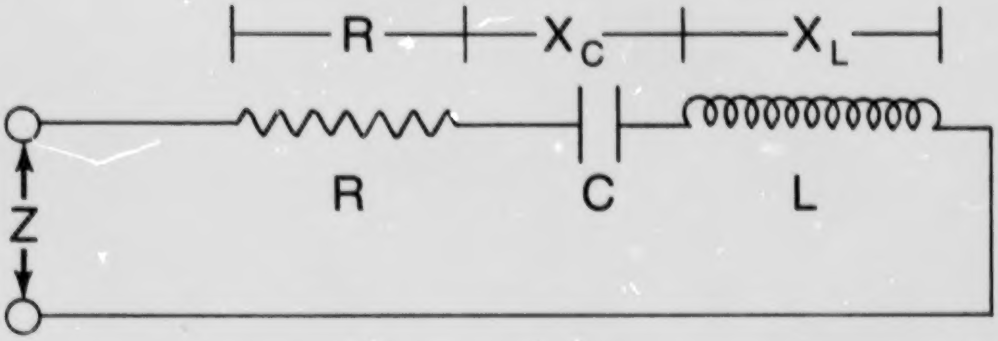
XI. Bandwidth

The formula for bandwidth, BW (or bandpass), equals f_r/Q where f_r is the resonant frequency, and Q is the quality of the circuit

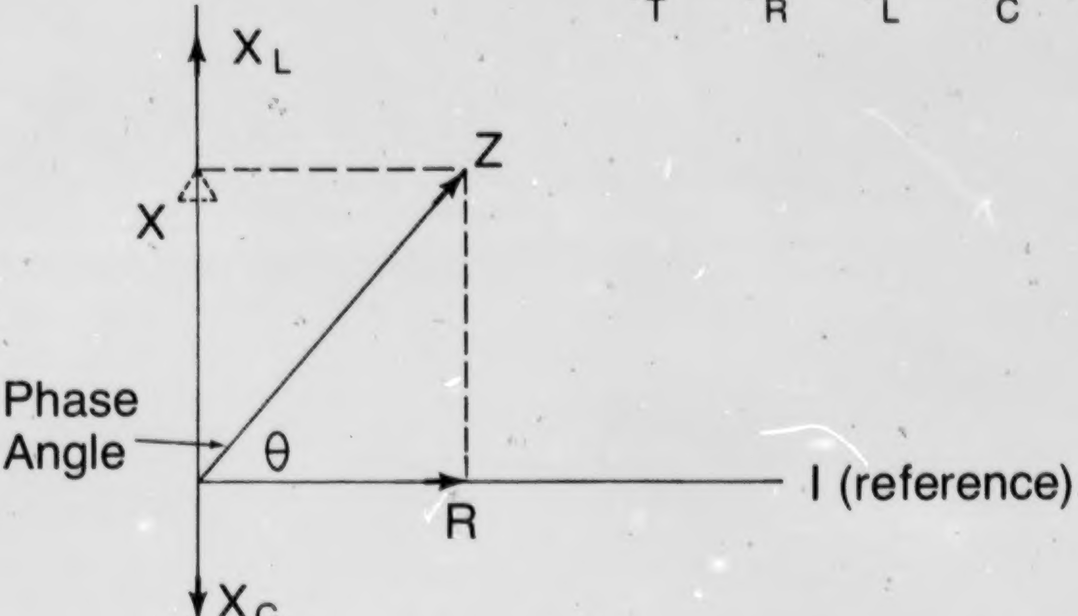


Bandwidth of a Series Circuit
(From f_1 to f_2; Equidistant from f_r)

Impedance Relationship in a Series RCL Circuit

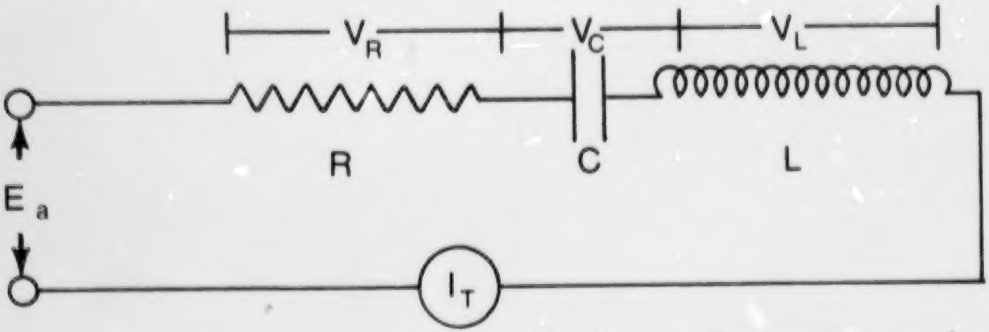


$$I_T = I_R = I_L = I_C$$

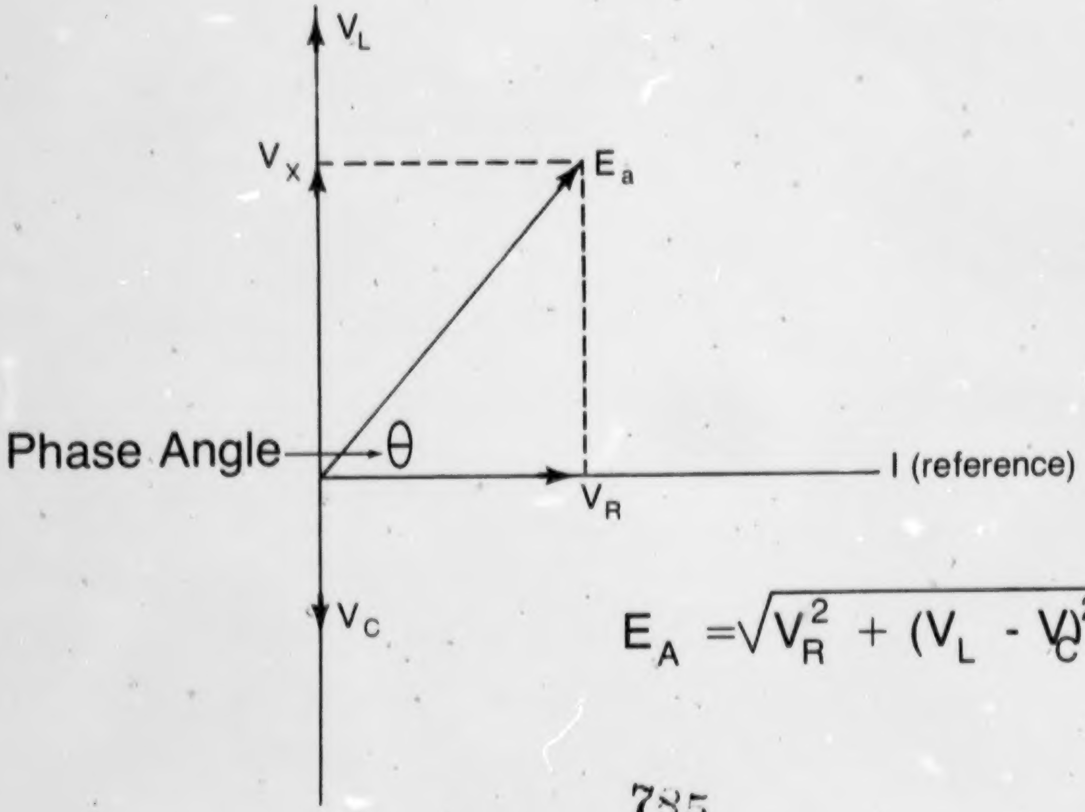

X_L
Z
X
Phase Angle
θ
I (reference)
R
X_C

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

Voltage Relationship in a Series RCL Circuit

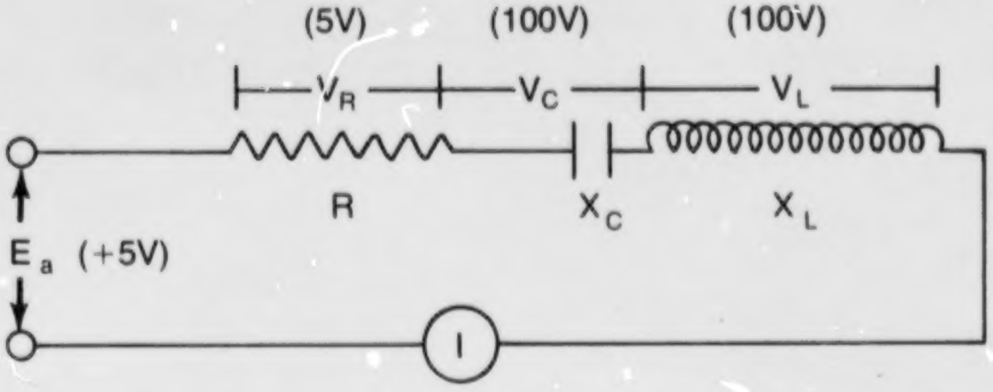

V_R
V_C
V_L
R
C
L
E_a
I_T

$$I_T = I_R = I_C = I_L$$

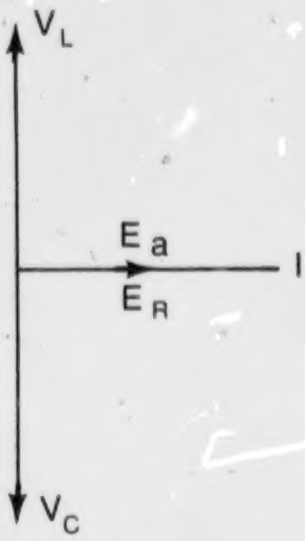

V_L
V_X
E_a
Phase Angle
θ
I (reference)
V_R
V_C

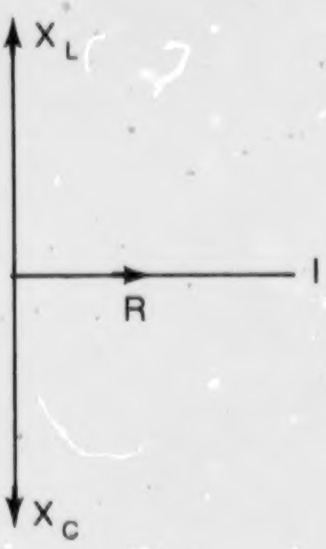
$$E_A = \sqrt{V_R^2 + (V_L - V_C)^2}$$

Resonance Relationship in a Series RCL Circuit


(5V)
(100V)
(100V)
V_R
V_C
V_L
R
X_C
X_L
E_a (+5V)
I

Phase Angle = 0°



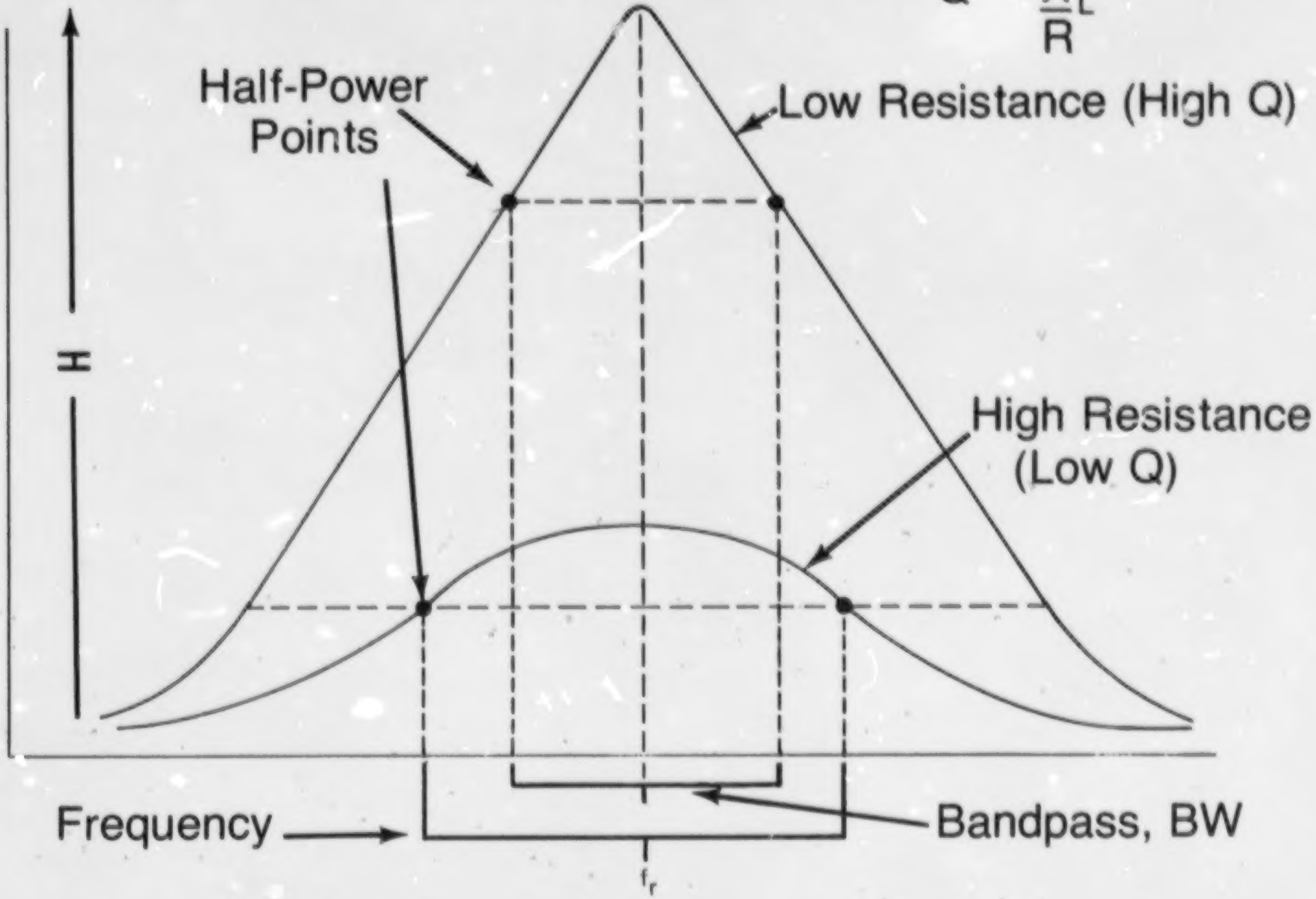


$E_L = E_C$; $E_a = E_R$

$X_C = X_L$; $Z = R$

Typical Resonant Curves

$$Q = \frac{X_L}{R}$$



SERIES RCL CIRCUITS
UNIT VIII

ASSIGNMENT SHEET #1--SOLVE FOR REACTANCE

A. The formula for computing total reactance, X_T is ______________________

B. If X_L is 10 ohms and X_C is 5 ohms, X_T equals ______________ ohms and the circuit is (capacitive) (inductive)

C. If X_L is 5 ohms and X_C is 10 ohms, X_T equals ______________ ohms and the circuit is (capacitive) (inductive)

D. The formula used to compute inductive reactance, X_L, is ______________

E. The formula used to compute capacitive reactance, X_C, is ______________

F. Capacitance is measured in ______________ (units) and capacitive reactance is measured in ______________________

G. Inductance is measured in ______________ and inductive reactance in ________

H. If a 1mH coil is in series with a 5Fd capacitor, the circuit will be (inductive) (capacitive) at 3 Hertz but will be (inductive) (capacitive) at 1KHz

I. Inductive reactance varies (directly) (inversely) with frequency

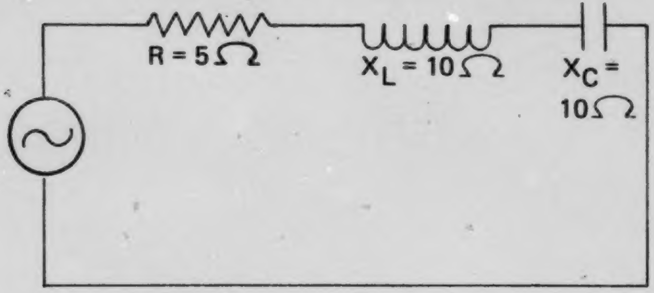
J. Capacitive reactance varies (directly) (inversely) with frequency

SERIES RCL CIRCUITS
UNIT VIII

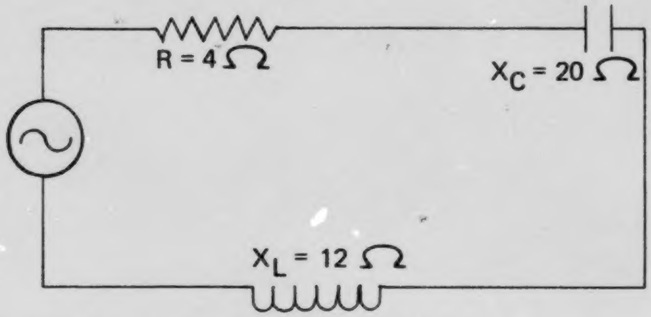
ASSIGNMENT SHEET #2--SOLVE FOR IMPEDANCE

(NOTE: In each circuit make a sketch of the impedance triangle.)

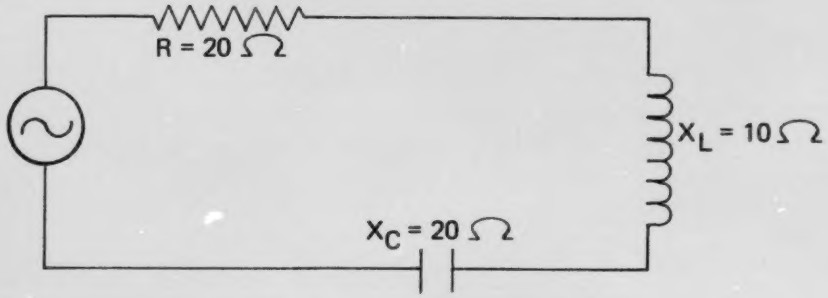
A. Compute impedance in the following circuit. Z = ____________



B. The impedance of the circuit below is ____________ ohms



C. The impedance in the following circuit is ____________



D. The effective reactance of the circuit in problem A is ____________

E. The effective reactance of the circuit in problem B is ____________

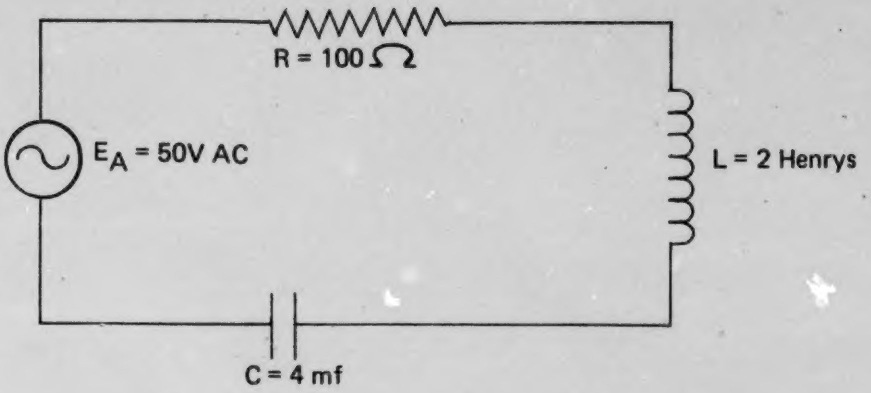
F. The effective reactance of the circuit in problem C is ____________

SERIES RCL CIRCUITS
UNIT VIII

ASSIGNMENT SHEET #3--SOLVE FOR PARAMETERS OF RESONANT CIRCUITS

Directions: Use the following circuit to solve all problems on this assignment sheet.

(NOTE: Be sure to include your units of measurement.)



A. The resonant frequency, f_r, equals____________________

B. The total current at resonance equals____________________

C. The inductive reactance, X_L, equals____________________

D. The capacitive reactance, X_C, equals____________________

E. The inductive voltage drop, V_L, equals____________________

F. The capacitive voltage drop, V_C, equals____________________

G. The resistive voltage drop, V_R, equals____________________

H. The power dissipated in the circuit, P, equals____________________

I. The Q of the circuit is____________________

J. The bandwidth, BW, of the circuit is____________________

SERIES RCL CIRCUITS
UNIT VIII

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

a. $(X_L - X_C)$

b. +5, inductive

c. -5, capacitive

d. $2 \pi fL$

e. $\frac{1}{2 \pi fC}$

f. farads, ohms

g. henrys, ohms

h. capacitive, inductive

i. directly

j. inversely

Assignment Sheet #2

a. 5 ohms

b. 8.94 ohms

c. 22.36 ohms

d. 0 ohms

e. -8 ohms (capacitive)

f. -10 ohms (capacitive)

Assignment Sheet #3

a. 56.8 (or 57) Hertz

b. 0.5 amps

c. 713 ohms

d. 713 ohms

e. 356.5 volts

f. 356.5 volts

g. 50 volts

h. 25 watts

i. 7.13

j. 7.96 or 8 Hertz

SERIES RCL CIRCUITS
UNIT VIII

JOB SHEET #1--DETERMINE RESONANCE IN A SERIES RCL CIRCUIT

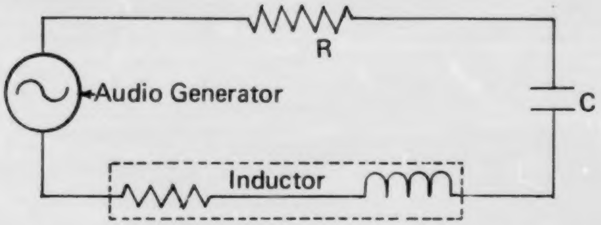
I. Tools and Equipment

- A. Audio generator
- B. Oscilliscope
- C. Multimeter
- D. 1 - μf capacitor
- E. 1H inductor
- F. 100-ohm resistor
- G. Linear graph paper

II. Procedure

A. Use your ohmmeter and measure the resistance of the 100-ohm resistor and the resistance of the inductor; record these measurements in the data table

B. Connect the resistor, inductor, and capacitor in series to the audio generator as follows:



C. Use the values of your capacitor and inductor to compute the expected resonant frequency of this circuit ($f_r = \frac{.159}{\sqrt{LC}}$)

D. Connect the multimeter across the generator output terminals and set the generator for maximum voltage at 100 Hz; vary the generator frequency around the value computed in Step C until the voltage output is at a minimum and make a mental note of the voltage output

E. Choose a generator voltage slightly less than the minimum noted above and set the generator to this value; this will be the applied voltage, E_a, for the following steps and must be maintained at all times

JOB SHEET #1

F. Remove the multimeter and connect the oscilloscope across the generator output terminals; observe carefully the indication on the oscilloscope because you must maintain a constant E_a (as indicated on the oscilloscope) for the remaining steps

G. Connect the multimeter across the 100-ohm resistor; read and record in the data table the voltage across the resistor, V_R, for generator frequencies of 80, 100, 120, 140, 160, 180, 200, 220, 240, and 260 Hz and be sure that your applied voltage E_a is the same for all of these frequencies

H. Adjust the generator to the frequency that gives the maximum V_R reading and be sure that E_a is at its correct value; record this resonant frequency of the circuit, F_O, in the data table along with its corresponding V_R

I. With the generator at F_O and E_A at its proper value, connect the oscilloscope across the resistor and observe the wave form

J. Move both leads in sequence and connect them across the capacitor and observe the wave form

(NOTE: Equipment grounds can cause improper indications.)

K. Repeat for the inductor; be sure to watch for shifts in both amplitude and in horizontal movement

L. Set the generator to 100Hz, and E_a to its correct value; using your oscilliscope, observe the voltage wave forms across the resistor, capacitor, and inductor

M. Turn the generator off

N. Use Ohm's Law and compute the circuit current, I_T, for each frequency; record each computed value in the data table $I_T = V_R/R$

O. Use Ohm's Law and compute the circuit impedance, Z_T, for each frequency; record each computed value in the data table $Z_T = E_a/I_T$

P. Prepare a graph by letting the horizontal scale be the various frequency settings listed in your data table. Plot the corresponding values of I_T on the vertical axis. Draw a smooth curve between these points (Include F_O)

Q. Plot the values of Z_T on the same graph and draw a smooth curve between these points

Discuss the following:

1. Does the computed resonant frequency, f_r of Step C equal the observed resonant frequency, F_O, of Step H? Explain any difference.

JOB SHEET #1

2. Why is the generator output voltage in step D at a minimum at the resonant frequency? (HINT: Is there any resistance inside the generator?)

3. On your graph compare the maximum value of I_T and the minimum value of Z_T. Do these occur at the same frequency?

4. Compare the minimum value of Z_T with the circuit's total resistance found in Step A; explain the difference

5. Why was there such a large difference between the capacitor voltage and the resistor voltage observed in Step I? Were the capacitor voltage and the inductor voltage observed in Step I equal but opposite in phase?

6. Explain why the inductor voltage was smaller than the capacitor voltage, in Step L; how do these voltages differ from those observed in Steps I, J, and K?

7. If this circuit was connected between a generator and a load, what frequency would be passed most easily? What impedance would be presented? How much greater would be the impedance if the frequency were 80 Hz lower? How much impedance for a frequency 80 Hz higher? (Use your graph for these answers.)

8. Does your graph confirm that impedance and current vary inversely with each other?

Data Table

E_a = ________volts

Measured Resistance: R = ______ R_L = _____

Frequency:	80 Hz	100	120	140	160	180	200	220	240	F_O = ___________
V_R										
I_T										
Z_T										

SERIES RCL CIRCUITS
UNIT VIII

NAME______________________

TEST

1. Match the terms on the right with the correct definitions.

_____a. A circuit containing resistance, inductance, and capacitance through which a common current flows

_____b. The opposition to current flow by a capacitor or an inductor

_____c. The total opposition to the flow of current

_____d. Condition of a circuit where the inductive and capacitive effects cancel each other

_____e. Section of frequency spectrum passing through a series resonant circuit

1. Impedance
2. Bandwidth
3. Reactance
4. Series RCL circuit
5. Resonance

2. Match the circuit condition on the right with the reactance in a series RCL circuit. (NOTE: The numbers on the right will be used more than once.)

_____a. X_T is positive

_____b. X_T equals zero

_____c. X_T is negative

_____d. X_L equals X_C

_____e. X_L is greater than X_C

_____f. X_C is greater than X_L

1. Circuit is inductive
2. Circuit is capacitive
3. Circuit is resistive

3. Select true statements regarding impedance in series RCL circuits by placing an "X" in the appropriate blanks.

_____a. Pure inductance causes current to lag the voltage by 90 degrees

_____b. Pure capacitance causes current to lag the voltage by 90 degrees

_____c. Leading voltages and lagging voltages tend to neutralize each other

_____d. Leading voltages and lagging voltages tend to reinforce each other _____e. In a purely inductive circuit, voltage leads current by 90 degrees

_____f. In a purely capacitive circuit, voltage lags current by 90 degrees

4. State the formula for computing impedance in a series RCL circuit.

$Z =$ ____________________

5. Match the voltages on the left with the proper relationship to the current in a series RCL circuit.

_____a. 0°	1. V_R
_____b. $+90^\circ$	2. V_L
_____c. -90°	3. V_C

6. State the formula for computing the applied voltage, E_A, in terms of voltage drops.

$E_A =$ ______________________________

7. List three conditions existing in a resonant series RCL circuit.

a. ______________________________

b. ______________________________

c. ______________________________

8. State the formula for computing resonant frequency.

$f_r =$ __________

9. Differentiate between resonant frequency variation with respect to capacitance and inductance in a tuned series RCL circuit by correctly completing the following sentences:

   a. In a tuned series RCL circuit, the resonant frequency varies (directly) (inversely) with the capacitance.

   b. In a tuned series RCL circuit, the resonant frequency varies (directly) (inversely) with the inductance

10. Select true statements regarding the Q of a series tuned circuit by placing an "X" in the appropriate blanks.

_____a. Q varies directly with resistance

_____b. Q varies inversely with resistance _____c. Q is a measure of the selectivity of the circuit

_____d. There is no formula for Q; it must be determined experimentally

11. State the formula for bandwidth.

    ____

12. Solve for reactance.

13. Solve for impedance.

14. Solve for parameters of resonant circuits.

15. Demonstrate the ability to determine resonance in a series RCL circuit.

    (NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

SERIES RCL CIRCUITS
UNIT VIII

ANSWERS TO TEST

1. a. 4 d. 5
   b. 3 e. 2
   c. 1

2. a. 1 d. 3
   b. 3 e. 1
   c. 2 f. 2

3. a, c, e, f

4. $Z = \sqrt{R^2 + (X_L - X_C)^2}$

5. a. 1
   b. 2
   c. 3

6. $E_A = \sqrt{V^2{}_R + (V_L - V_C)^2}$

7. Any three of following:
   a. Resonance occurs when inductive effect equals capacitive effect
   b. Impedance is at minimum value and equal to R
   c. Current is maximum, limited only by the resistance R
   d. Phase angle between voltage and current is zero
   e. V_L and V_C are equal and are larger than E_A

8. $f_r = \frac{1}{2\pi\sqrt{LC}}$ or $\frac{1}{\sqrt{6.28\ LC}}$ or $\frac{.159}{\sqrt{LC}}$

9. a. Inversely
   b. Inversely

10. b, c

11. f_r/Q

12. Evaluated to the satisfaction of the instructor.

13. Evaluated to the satisfaction of the instructor.

14. Evaluated to the satisfaction of the instructor.

15. Performance skills evaluated to the satisfaction of the instructor.

PARALLEL RCL CIRCUITS
UNIT IX

UNIT OBJECTIVE

After completion of this unit, the student should be able to state formulas for computing total current and impedance in a parallel RCL circuit, select true statements related to tuned parallel RCL circuits and the Q of a tuned circuit. The student should also be able to analyze a parallel resonant circuit and determine the frequency of a RCL parallel circuit. This knowledge will be evidenced by correctly performing the procedures outlined on the assignment and job sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms associated with parallel RCL circuits with the correct definitions.
2. Select true statements concerning voltage and currents in a parallel RCL circuit.
3. State the formula for computing total current in a parallel RCL circuit.
4. State the formula for computing impedance in a parallel RCL circuit.
5. Select true statements relating to resonance in parallel RCL circuits.
6. State the formula for computing the resonant frequency of a parallel RCL circuit.
7. Select true statements relating to tuned parallel RCL circuits.
8. Select true statements relating to the Q of a parallel tuned circuit.
9. State the formula for bandwidth of a parallel RCL circuit.
10. Complete a chart of characteristics of series and parallel resonant circuits.
11. Solve problems related to RL and RC parallel circuits.
12. Solve problems related to parallel RCL circuits.
13. Analyze a parallel resonant circuit.
14. Demonstrate the ability to determine the resonant frequency of an RCL parallel circuit.

PARALLEL RCL CIRCUITS
UNIT IX

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information, assignment, and job sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information and assignment sheets.

VI. Demonstrate and discuss the procedures outlined in the job sheet.

VII. If available, use an oscilloscope to show the current shifts in parallel circuits; demonstrate the various methods of using both series and parallel tuned circuits for filters; and, if desired, place more emphasis upon phasor (vector) analysis.

VIII. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

  A. Objective sheet

  B. Information sheet

  C. Transparency masters

    1. TM 1--Current Relationship in a Parallel RCL Circuit
    2. TM 2--Current Relationship in a Parallel RL Circuit
    3. TM 3--Current Relationships in a Parallel RC Circuit
    4. TM 4--Resonance Relationship in a Parallel RCL Circuit
    5. TM 5--Tuned Parallel Circuit Curves

  D. Assignment sheets

    1. Assignment Sheet #1--Solve Problems Related to RL and RC Parallel Circuits
    2. Assignment Sheet #2--Solve Problems Related to Parallel RCL Circuits

    3. Assignment Sheet #3--Analyze a Parallel Resonant Circuit

  E. Answers to assignment sheets

  F. Job Sheet #1--Determine the Resonant Frequency of an RCL Parallel Circuit

  G. Test

  H. Answers to Test

II. References:

A. Grob, Bernard. *Basic Electronics.* New York: McGraw-Hill Book Co., 1977.

B. *Fundamentals of Electricity.* Fort Sill, OK: U.S. Army Field Artillery School, 1975.

C. Robertson, L.P. *Instrumentation and Measurements Handbook.* Albuquerque, NM: Sandia Laboratories, 1971.

D. Tinnell, R.W. *Electricity.* Albany, NY: Delmar Publishers, 1975.

PARALLEL RCL CIRCUITS
UNIT IX

INFORMATION SHEET

I. Terms and definitions

A. Parallel RCL circuit--A circuit containing resistance, capacitance, and inductance across which a common voltage is applied

(NOTE: In parallel circuits the current divides and reunites.)

B. Node--The location where current divides or reunites in parallel circuits

C. Resonance--The condition where inductive and capacitive effects cancel each other

D. Filter--A circuit designed to pass or suppress certain frequencies

E. Tank circuit--An inductor and capacitance connected in parallel

II. Voltage and currents in a parallel RCL circuit (Transparencies 1,2,and 3)

A. Voltage is common to all components and is used as the reference

B. Current through a resistive branch, I_R, is in phase with the voltage

C. Current through an inductive branch, I_L, lags the voltage by 90°

D. Current through a capacitive branch, I_C, leads the voltage by 90°

E. Reactive current, I_X, is the vector sum of the inductive current and the capacitive current $(I_C - I_L)$

III. Formula for total current in a parallel RCL circuit (Transparency 1)

Total current, $I_T = \sqrt{I_R^2 + (I_C - I_L)^2}$

IV. Formula for impedance, Z, in a parallel RCL circuit (Transparency 1)

Impedance, $Z = \frac{E_A}{I_T}$

INFORMATION SHEET

V. Resonance in a parallel RCL circuit (Transparency 4)

A. Resonance occurs when inductive effects equal capacitive effects

B. Impedance of the circuit is at maximum value and equals E_A/I_T

C. Current is at minimum value and equals I_R

D. The phase angle between voltage and current is zero

E. I_L and I_C are equal and are usually larger than I_R

VI. Formula for resonant frequency

Resonant frequency, (F_R), equals $\frac{1}{2\pi\sqrt{LC}} = \frac{1}{6.28\sqrt{LC}} = \frac{.159}{\sqrt{LC}}$

(NOTE: The formula for resonant frequency is approximately the same for series and parallel circuits.)

VII. Tuned parallel circuits (Transparency 5)

A. Increasing inductance or capacitance decreases the resonant frequency

B. Decreasing inductance or capacitance increases the resonant frequency

C. Currents close to the resonant frequency but inside the bandpass are attenuated (meet much opposition)

D. Parallel tuned circuits used to block currents close to the resonant frequency are called filters

VIII. Q of a parallel tuned circuit

A. Q is a measure of the selectivity of the circuit

B. Q varies inversely with resistance

(NOTE: Most of the resistance is found in the coil, so this is the resistance value used.)

C. The formula for Q is X_L/R

D. The relationship beween tank current, total current, and Q is shown by:

$I_C = I_T \times Q$

(NOTE: I_C is sometimes called the "tank" current.)

INFORMATION SHEET

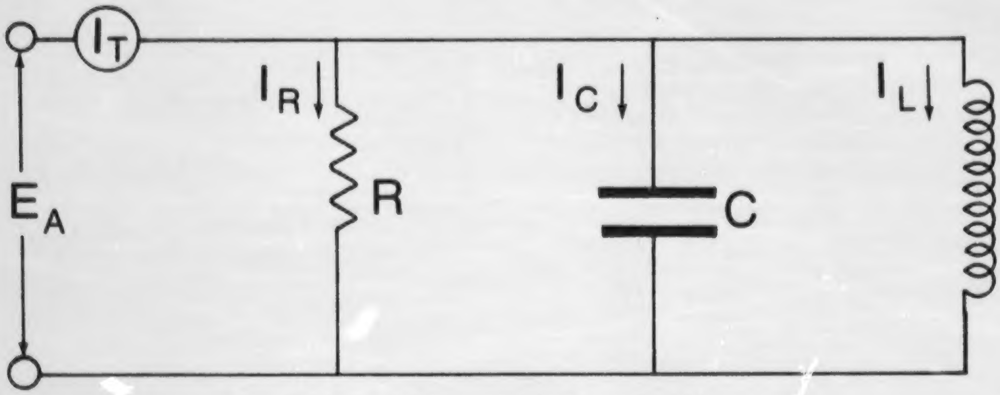
IX. Formula for bandwidth (BW) equals F_R/Q

(NOTE: The formula for bandwidth is the same for both series and parallel RCL circuits.)

X. Summary of characteristics of series and parallel resonant circuits

	Series Resonant Circuit	Parallel Resonant Circuit
Impedance	Minimum	Maximum
Current	Maximum	Minimum
Impedance at Resonance	Resistive	Resistive
Impedance below Resonance	Capacitive	Inductive
Impedance above Resonance	Inductive	Capacitive
Impedance Formula	$Z = \sqrt{R^2 + (X_L - X_C)^2}$	$Z = \frac{E_A}{I_T}$
Formula for Q	$Q = \frac{X_L}{R}$	$Q = \frac{X_L}{R}$
Formula for Bandwidth(BW)	$BW = \frac{F_R}{Q}$	$BW = \frac{F_R}{Q}$
Formula for Resonant Frequency (F_R)	$F_R = \frac{1}{2\pi\sqrt{LC}}$	$F_R = \frac{1}{2\pi\sqrt{LC}}$

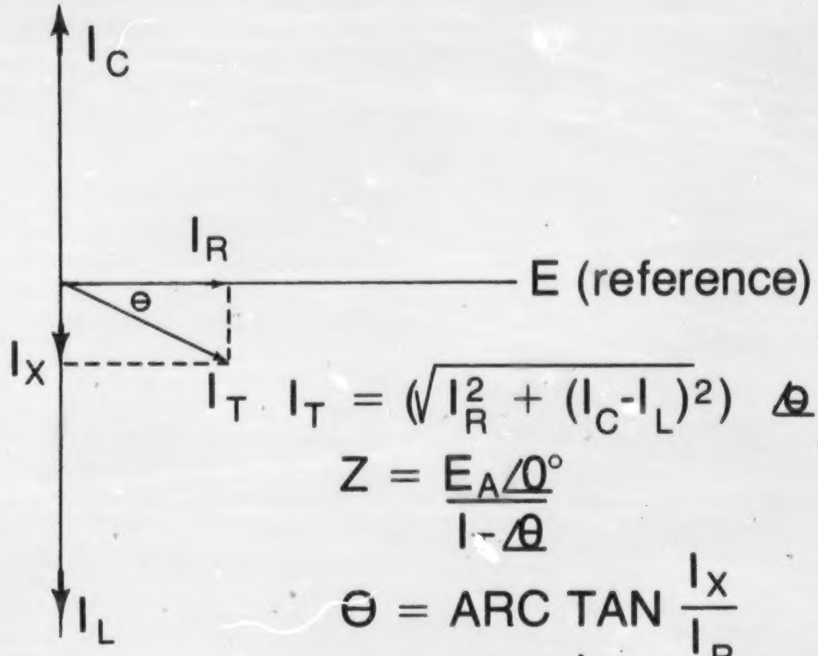
Current Relationship in a Parallel RCL Circuit



I_T
I_R
I_C
I_L
E_A
R
C

$$E_A = V_R = V_C = V_L$$

Phase Angle



I_C
I_R
E (reference)
θ
I_X
I_T
I_L

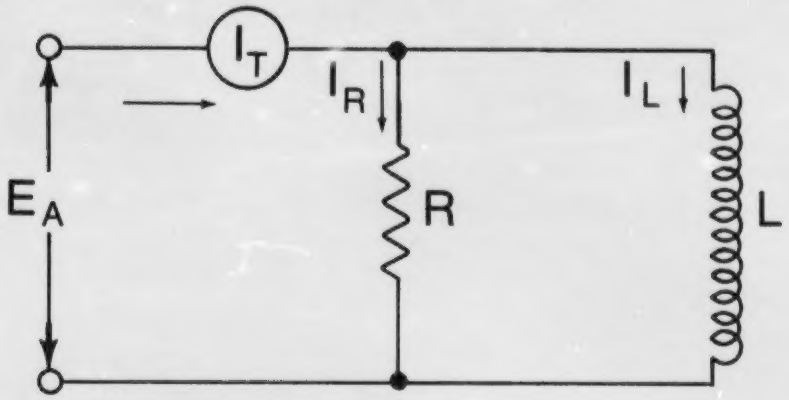
$$I_T = \left(\sqrt{I_R^2 + (I_C - I_L)^2}\right) \angle\theta$$

$$Z = \frac{E_A \angle 0^\circ}{I \angle -\theta}$$

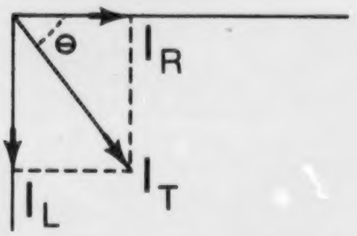
$$\theta = \text{ARC TAN } \frac{I_X}{I_R}$$

$$\theta = \text{ARC COS } \frac{I_R}{I_T}$$

Current Relationship in a Parallel RL Circuit


I_T
I_R
I_L
E_A
R
L

$$E_A = E_R = E_L$$

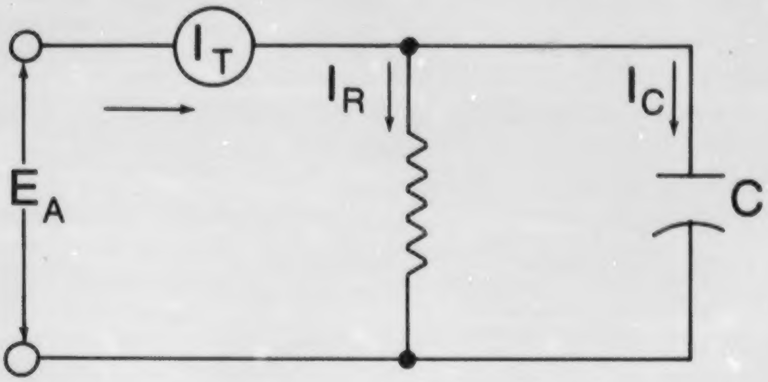

E (Reference)
θ
I_R
I_T
I_L

$$I_T = \sqrt{I_R^2 + I_L^2}$$

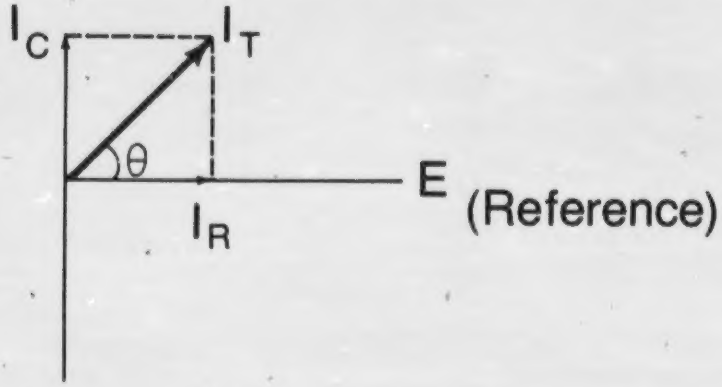
$$Z = E_A / I_T$$

$$\theta = \text{ARC COS}\ (I_R / I_T)$$

Current Relationships In A Parallel RC Circuit



$$E_A = E_R = E_C$$

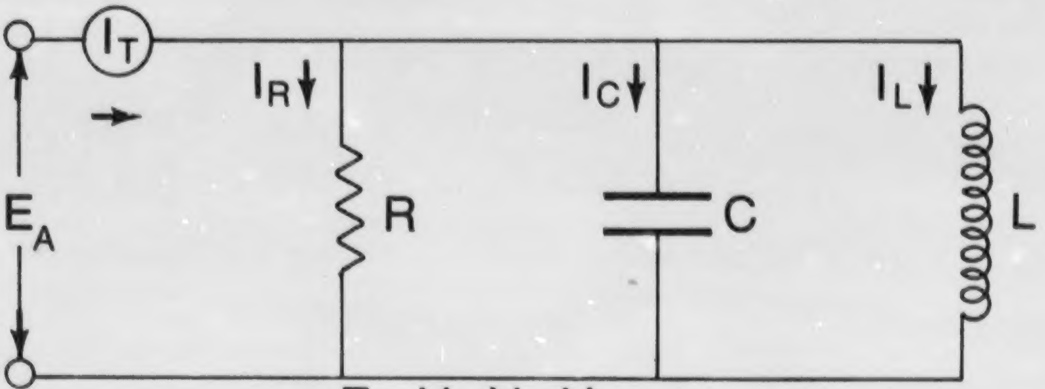

I_C
I_T
θ
I_R
E (Reference)

$$I_T = \sqrt{I_R^2 + I_C^2}$$

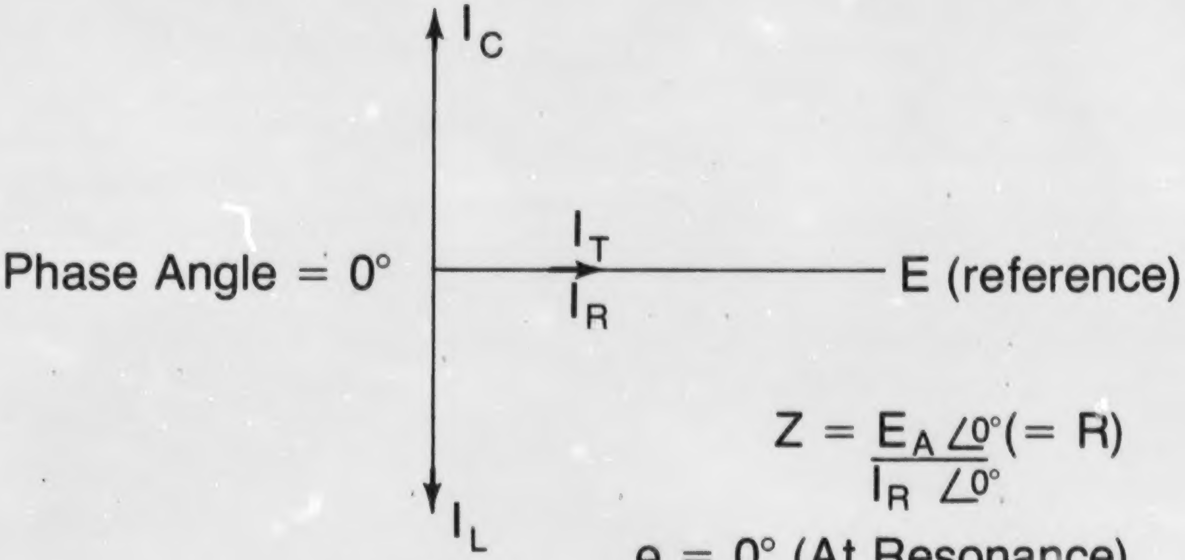
$$Z = E_A / I_T$$

$$\Theta = \text{ARC COS } (I_R/I_T)$$

Resonance Relationship in a Parallel RCL Circuit


I_T
I_R
I_C
I_L
E_A
R
C
L

$E_A = V_R = V_C = V_L$


I_C
Phase Angle = 0°
I_T
I_R
E (reference)
I_L

$$Z = \frac{E_A \angle 0°}{I_R \angle 0°} (= R)$$

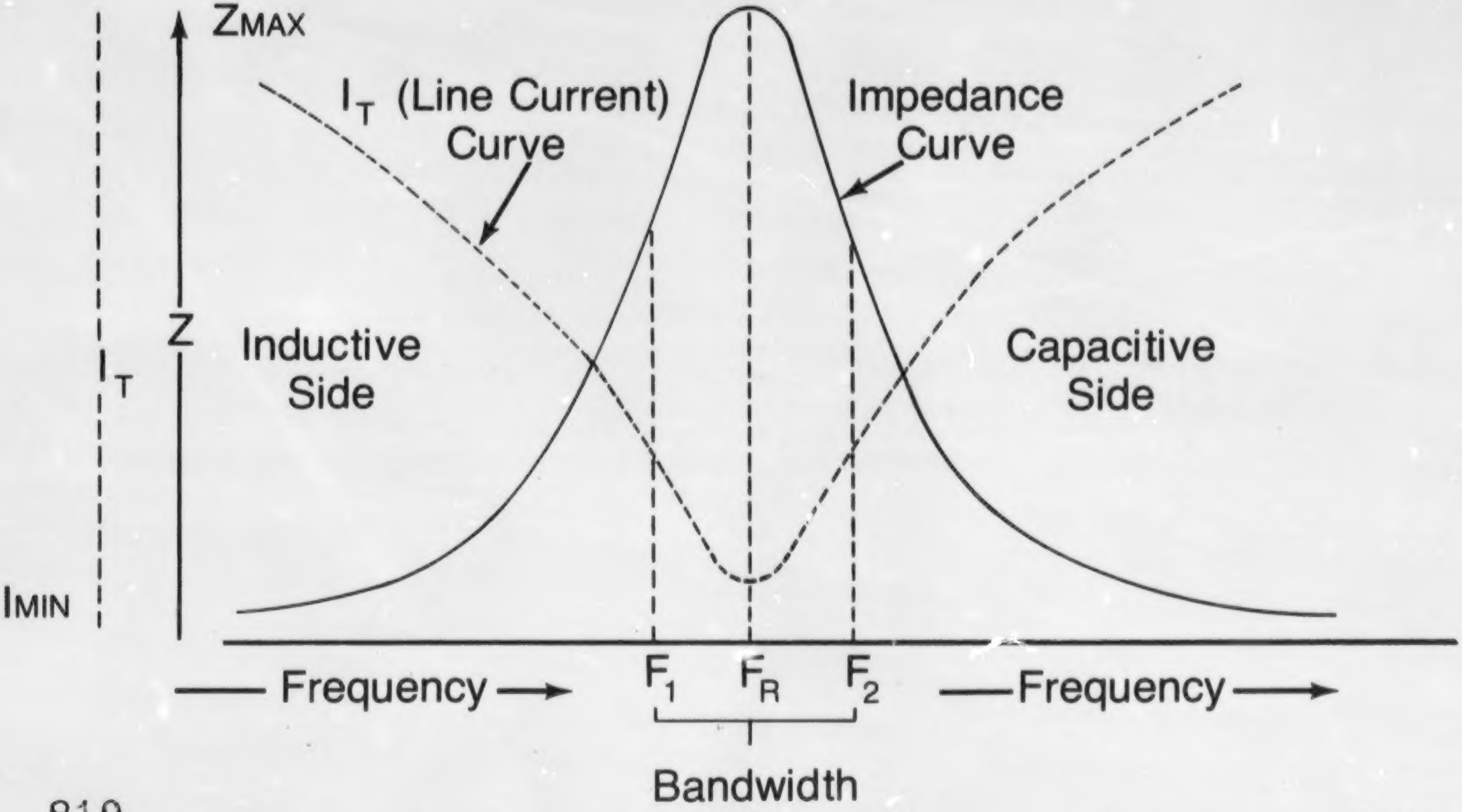
$\theta = 0°$ (At Resonance)

$I_C = I_L$

$I_T = I_R$

$Z = R$

Tuned Parallel Circuit Curves



810

811

TM 5

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PARALLEL RCL CIRCUITS
UNIT IX

ASSIGNMENT SHEET #1--SOLVE PROBLEMS RELATED TO RL AND RC PARALLEL CIRCUITS

1. State the formulas for solving the values listed below in parallel circuits

A. I_R = ____________

B. I_L = ____________

C. I_C = ____________

D. I_T = ____________

E. Z = ____________

2. If the following statement describes an impedance that is inductive, place an "L" in the space and if it is capacitive, place a "C"

_____a. A circuit where I_L is larger than I_C

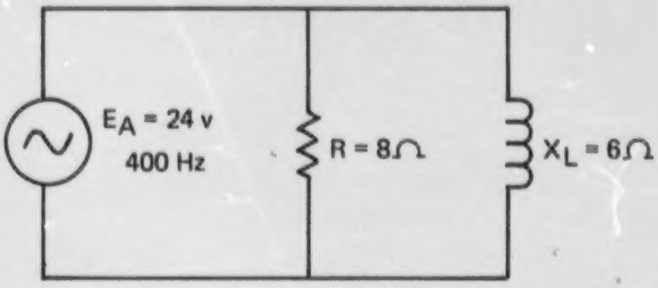
_____b. A circuit where I_C is larger than I_L

_____c. A circuit containing only an inductor and resistor in parallel

_____d. A parallel circuit where X_L is larger than X_C

_____e. A parallel circuit where X_C is larger than X_L

3. Solve for the indicated values in the circuit below



a. E_R = ____________

b. E_L = ____________

c. I_R = ____________

d. I_L = ____________

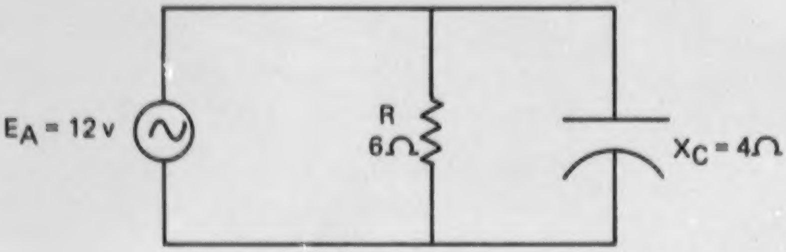
e. I_T = ____________

f. Z = ____________

ASSIGNMENT SHEET #1

4. Draw the phasor (vector) diagram of the currents in the circuit of problem 3; from this sketch, the phase angle equals________________________

5. Solve for the indicated values of the circuit below



a. $E_R =$ ____________________

b. $E_C =$ ____________________

c. $I_R =$ ____________________

d. $I_C =$ ____________________

e. $I_T =$ ____________________

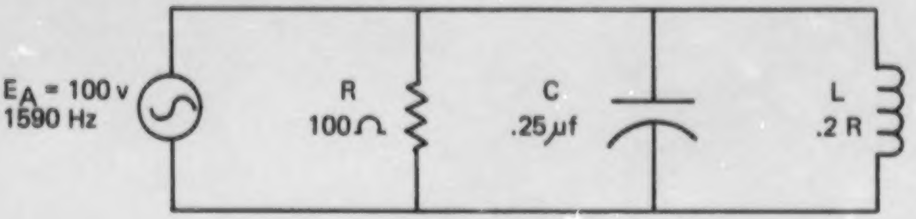
f. Z = ____________________

6, Draw the phasor (vector) diagram of the circuit of problem 5; the phase angle in this circuit is________________________________

PARALLEL RCL CIRCUITS
UNIT IX

ASSIGNMENT SHEET #2--SOLVE PROBLEMS RELATED TO PARALLEL RCL CIRCUITS

1. In the circuit below, a 100 ohm resistor, a .2 henry inductor, and a .25 μf capacitor are connected in parallel across a source voltage of 100 volts at 1590 hertz; solve for the indicated parameters



a. X_L = ______________

b. X_C = ______________

c. I_R = ______________

d. I_C = ______________

e. I_L = ______________

f. I_T = ______________

g. Z = ______________

h. P_T = ______________

i. P_A = ______________

j. Power Factor, PF, = ______________

k. Phase Angle, θ = ______________

2. Make a sketch of the phasor (vector) diagram of the above circuit.

PARALLEL RCL CIRCUITS
UNIT IX

ASSIGNMENT SHEET #3–ANALYZE A PARALLEL RESONANT CIRCUIT

1. In a parallel circuit, impedance is a function of the_____of the voltage applied

2. At parallel resonance,

   _____a. Impedance is minimum

   _____b. Impedance is maximum

   _____c. Current is minimum

   _____d. Current is maximum

3. Frequencies higher than the resonant frequency of a parallel RCL circuit causes more current to be in the

   _____a. capacitive branch

   _____b. inductive branch

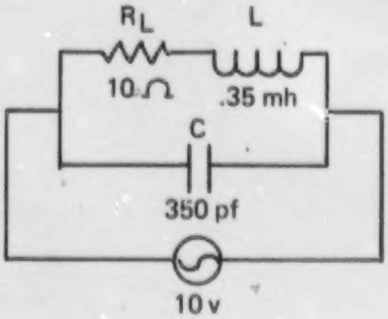
4. Frequencies lower than the resonant frequency of a parallel RCL circuit cause more current to be in the

   _____a. capacitive branch

   _____b. inductive branch

5. The formula for computing resonant frequency is_____________________

6. An inductor and capacitor are connected as shown in the schematic below and ten volts are applied; solve for the indicated parameters



a. Resonant Frequency, F_R, = _____________________

b. The Q of the circuit = _____________________

c. I_C (also called tank current) = _____________________

ASSIGNMENT SHEET #3

d. I_T (use Q and I_C) = ______________________________

e. Impedance, Z, = ______________________________

f. Power consumed, P_T, = ______________________________

g. Bandwidth, BW, = ______________________________

PARALLEL RCL CIRCUITS
UNIT IX

ANSWERS TO ASSIGNMENT SHEETS

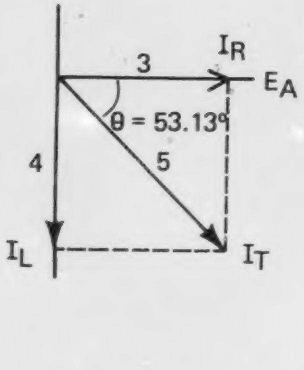
Assignment Sheet #1

1. a. E_a/R d. $\sqrt{I_R^2 + (I_C - I_L)^2}$
   b. E_a/X_L e. E_A/I_T
   c. E_a/X_C

2. a. L
   b. C
   c. L
   d. C
   e. L

3. a. $24V\angle 0°$
   b. $24V\angle 0°$
   c. $3A\ \angle 0°$
   d. $4A\angle -90°$
   e. $5A\angle -53.13°$
   f. $4.8\ \angle +53.13°$

4.



5. a. $12\text{V}\angle 0$

   b. $12\text{V}\angle 0$

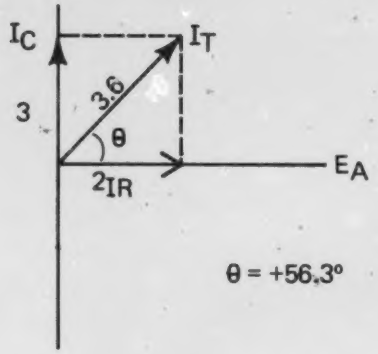
   c. $2\text{A}\angle 0$

   d. $3\text{A}\angle +90^\circ$

   e. $3.6\text{A}\angle +56.3^\circ$

   f. $3.33\ \Omega\angle -56.3^\circ$

6.



Assignment Sheet #2

1. a. 1,997 or approximately 2,000 ohms

   b. 400 ohms

   c. 1 ampere

   d. 0.25 ampere

   e. .05 ampere

   f. 1.0193 or 1.02 amperes

   g. 98.039 or approximately 98 ohms

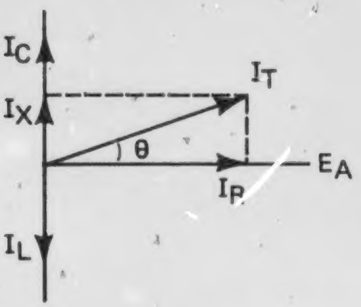
   h. 100 watts

   i. 102 volt-amperes

   j. .98

   k. 11.3° leading

2.



Assignment Sheet #3

1. frequency

2. C

3. A

4. B

5. $F_R = \frac{1}{2\pi\sqrt{LC}}$

6. a. 455,000 Hz or 455 KHz

   b. $Q = \frac{XL}{R} = \frac{1000\Omega}{10\Omega} = 100$

   c. $I_C = \frac{Ea}{X_c} = \frac{10V}{1000\Omega} = .01A$ or 10mA

   d. $I_T = \frac{Ic}{Q} = \frac{.01}{100} = .0001A$ or .1mA

   e. $Z = \frac{Ea}{I_T} = \frac{10V}{.0001A} = 10K\Omega$

   f. $P_T = E_a \times I_t = .001$ watt

   g. $BW = \frac{F_R}{Q} = \frac{455\ KHz}{100} = 4.55\ KHz$

PARALLEL RCL CIRCUITS
UNIT IX

JOB SHEET #1--DETERMINE THE RESONANT FREQUENCY OF AN RCL PARALLEL CIRCUIT

I. Tools and equipment

- A. Audio frequency generator
- B. Multimeter (electronic type)
- C. Ammeter, 0-150μA
- D. One capacitor, .001 microfarad
- E. One resistor, 10 Kohms, 1 watt
- F. One inductor, 10 millihenry
- G. Graph paper

II. Procedure

- A. Connect the circuit as shown in the following schematic

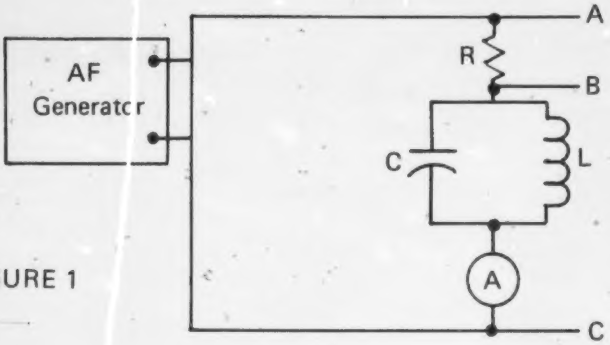


FIGURE 1

- B. Calculate the resonant frequency, F_R = ____________________Hz
- C. Adjust the audio frequency generator to the frequency calculated in step B
- D. Adjust the generator for maximum output
- E. Connect your voltmeter which is set to the 5V AC range across the tank circuit (points B and C) making sure that the common leads of the generator and the voltmeter are both connected to point C

JOB SHEET #1

F. Adjust the generator above and below the calculated frequency (step B) until there is a maximum voltage reading and a minimum reading on the ammeter

G. Record the frequency determined in Step B in the data table; this is the true F_R

H. Adjust the generator for an output of one volt (points B to C)

I. Measure the voltage, V_C obtained in Step F in the data table

J. Enter V_C obtained in Step F in the data table

K. Measure and enter the total current, I_T, as indicated by the ammeter

L. Calculate the inductive reactance, X_L, at the resonant frequency, and enter in the data table

M. Compute and enter the capacitive reactance, X_C

N. Calculate I_L and I_C and enter into the data table

O. Calculate the parallel tank circuit impedance, Z, and enter into the data table

P. Repeat Steps H through O at 10 kilohertz steps above and below the resonant frequency; be sure to adjust the generator for one volt output with each change of frequency

Q. Plot the tank circuit impedance (vertical axis) versus frequency points (horizontal axis) as calculated and enter in the data table

R. Connect the points to obtain a response curve

S. Discuss the following:

1. Explain the difference between the true resonant frequency and the calculated resonant frequency
2. Why is the current a minimum at the resonant frequency?
3. Does the tank circuit pass or block currents near the resonant frequency?
4. Is this a low Q or a high Q circuit? Explain ____________________
5. Is the total impedance larger than the series resistor or approximately equal to it? Why?

JOB SHEET #1

6. What is the bandwidth shown on your graph? Does this correspond with the bandwidth formula?

DATA TABLE

FREQUENCY	V_C (tank)	I_T	X_L	X_C	I_L	I_C	Z (tank)
(F_R - 30KHz)							
(F_R - 20KHz)							
(F_R - 10KHz)							
F_R = ______							
(F_R + 10KHz)							
(F_R + 20KHz)							
(F_R + 30KHz)							

PARALLEL RCL CIRCUITS
UNIT IX

NAME ______________________________

TEST

1. Match the terms on the right with the correct definitions.

_____ a. A circuit containing resistance, capacitance, and inductance across which a common voltage is applied

_____ b. The location where current divides or reunites in parallel circuits

_____ c. The condition where inductive and capacitive effects cancel each other

_____ d. A circuit designed to pass or suppress certain frequencies

_____ e. An inductor and capacitance connected in parallel

1. Filter
2. Node
3. Tank circuit
4. Parallel RCL circuit
5. Resonance

2. Select true statements concerning voltage and currents in a parallel RCL circuit by placing an "X" in the appropriate blanks.

_____ a. Voltage is common only to certain components and therefore cannot be used as a reference

_____ b. Current through a resistive branch, I_R, is in phase with the voltage

_____ c. Current through an inductive branch, I_L, lags the voltage by 90°

_____ d. Current through a capacitive branch, I_C, leads the voltage by 90°

_____ e. Reactive current, I_X, is the vector sum of the inductive current and the tank current

3. State the formula for computing total current in a parallel RCL circuit.

I_T = ______________________________

4. State the formula for computing impedance, Z, in a parallel RCL circuit.

Z = ______________________________

5. Select true statements relating to resonance in a parallel RCL circuit by placing an "X" in the appropriate blanks.

_____a. The phase angle between voltage and current is zero

_____b. Current is at maximum value

_____c. I_R is considerably larger than I_C, depending upon the Q of the circuit

_____d. Impedance of the circuit is at maximum value and equals E_A/I_T

_____e. Resonance occurs when inductive effects equal capacitive effects

_____f. Impedance of the circuit is at minimum value

_____g. I_L and I_C are equal and are usually larger than I_R

_____h. Phase angle between voltage and current is either 90° or -90°

6. State the formula for computing the resonant frequency of a parallel RCL circuit.

F_R = ______________________________

7. Select the true statements relating to tuned parallel circuits by placing an "X" in the appropriate blanks.

_____a. Increasing inductance decreases the resonant frequency

_____b. Decreasing inductance decreases the resonant frequency

_____c. Increasing capacitance decreases the resonant frequency

_____d. Decreasing capacitance decreases the resonant frequency

_____e. Currents close to the resonant frequency but inside the bandpass are attenuated

_____f. Currents close to the resonant frequency but inside the bandpass are passed

_____g. Parallel tuned circuits used to block currents close to the resonant frequency are called filters

8. Select true statements relating to the Q of a parallel tuned circuit by placing an "X" in the appropriate blanks.

_____a. Q varies inversely with resistance

_____b. The formula for Q is $\frac{R}{X_L}$

_____c. The relationship between tank current, total current, and Q is $I_C = I_T \times Q$

_____d. Q varies directly with resistance

_____e. Q is a measure of the selectivity of the circuit

9. State the formula for bandwidth.

BW = ______________________________

10. Complete the characteristics of series and parallel resonant circuits by filling in the blanks under parallel resonant circuits in the following chart.

	Series Resonant Circuit	Parallel Resonant Circuit
Impedance	Minimum	a.__________
Current	Maximum	b.__________
Impedance at Resonance	Resistive	c.__________
Impedance below Resonance	Capacitive	d.__________
Impedance above Resonance	Inductive	e.__________
Impedance Formula	$Z = \sqrt{R^2 + (X_L - X_C)^2}$	f.__________
Formula for Q	$Q = \frac{X_L}{R}$	g.__________
Formula for Bandwidth(BW)	$BW = \frac{F_R}{Q}$	h.__________
Formula for Resonant Frequency (F_R)	$F_R = \frac{1}{2\pi\sqrt{LC}}$	i.__________

11. Solve problems related to RL and RC parallel circuits.
12. Solve problems related to parallel RCL circuits.
13. Analyze a parallel resonant circuit.
14. Demonstrate the ability to determine the resonant frequency of an RCL parallel circuit.

(NOTE: If these activities have not been completed prior to the test, ask the instructor when they should be completed.)

PARALLEL RCL CIRCUITS
UNIT IX

ANSWERS TO TEST

1. a. 4
   b. 2
   c. 5
   d. 1
   e. 3

2. b, c, d

3. $I_T = \sqrt{I_R{}^2 + (I_C - I_L)^2}$

4. $Z = \dfrac{E_A}{I_T}$

5. a, d, e, g

6. $F_R = \dfrac{1}{2\pi\sqrt{LC}} = \dfrac{1}{6.28\sqrt{LC}} = \dfrac{.159}{\sqrt{LC}}$

7. a, c, e, g

8. a, c, e

9. $BW = F_R/Q$

10. a. Maximum
    b. Minimum
    c. Resistive
    d. Inductive
    e. Capacitive
    f. $Z = \dfrac{E_A}{I_T}$
    g. $Q = X_L/R$
    h. $BW = \dfrac{F_R}{Q}$
    i. $F_R = \dfrac{1}{2\pi\sqrt{LC}}$

11. Evaluated to the satisfaction of the instructor.

12. Evaluated to the satisfaction of the instructor.

13. Evaluated to the satisfaction of the instructor.

14. Performance skills evaluated to the satisfaction of the instructor.

APPLYING FOR A JOB
UNIT I

UNIT OBJECTIVE

After completion of this unit, the student should be able to prepare a resume, write a letter of application, complete an application form and write a follow-up letter. This knowledge will be evidenced by correctly performing the procedures outlined on the assignment sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms associated with applying for a job with correct definitions.
2. List sources for locating job openings.
3. List three methods of applying for a job.
4. Select information asked for on application forms.
5. Distinguish between employer and employee expectations.
6. Select attributes and attitudes desired by employers during personal interviews.
7. Select examples of proper conduct during a job interview.
8. Prepare a resume.
9. Write a letter of application.
10. Complete an application form for a job in electronics.
11. Write a follow-up letter after an interview.

APPLYING FOR A JOB
UNIT I

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information and assignment sheets.

III. Discuss unit and specific objectives.

IV. Discuss information and assignment sheets.

V. Provide samples of various application forms.

VI. Invite personnel officer and technical interviewer to discuss job interviewing techniques.

VII. Role play an interview on video tape if possible.

VIII. Discuss with students desirable attributes of electronics worker.

IX. Arrange for an interviewer from industry to assist with part B of Assignment Sheet #3.

X. Provide opportunity to take sample entry-level employment tests.

XI. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

  A. Objective sheet

  B. Information sheet

  C. Assignment sheets

    1. Assignment Sheet #1--Prepare a Resume

    2. Assignment Sheet #2--Write a Letter of Application

    3. Assignment Sheet #3--Complete an Application Form for a Job in Electronics

    4. Assignment Sheet #4--Write a Follow-up Letter After an Interview

  D. Test

  E. Answers to test

II. References:

A. Blackledge, Walter L., Ethel H. Blackledge, and Helen J. Keely. *You and Your Job.* Cincinnati: South-Western Pub. Co., 1967.

B. Kimbrell, Grady, and Ben S. Vineyard. *Succeeding in the World of Work.* Bloomington, IL: McKnight & McKnight, 1970.

C. *Occupational Child Development.* Stillwater, OK: Mid-America Vocational Curriculum Consortium, 1975.

D. *Residential Wiring.* Stillwater, OK: Mid-America Vocational Curriculum Consortium, 1978.

APPLYING FOR A JOB
UNIT I

INFORMATION SHEET

I. Terms and definitions

- A. Award--Recognition received for outstanding achievement
- B. Extra-curricular activities--The clubs, organizations, and social or church groups in which one participates
- C. Fringe benefits--The extras provided by an employer such as paid vacations, sick leave, and insurance protection
- D. Qualifications--The experience, education, and physical characteristics which suit a person to a job
- E. Resume--A brief (usually typed) summary of one's qualifications and experiences that is used in applying for a job
- F. Vocational preparation--The courses taken and the skills acquired in school or through work experience

II. Sources for locating job openings

- A. Classified ads
- B. Employment offices

  (NOTE: You can use government offices or private offices.)
- C. Local labor union business offices
- D. School officials

  (NOTE: Your teacher and counselor or employment coordinator will be glad to help you.)
- E. Workers in electronic occupations

  (NOTE: Current workers will often know of openings that are not publicly advertised.)

III. Methods of applying for a job

- A. Letter
- B. Telephone
- C. In person

INFORMATION SHEET

IV. Information that may be asked for on an application form

  A. Name and address
  B. Phone number
  C. Social security number
  D. Age, height, weight
  E. Education
  F. Experience
  G. Next of kin
  H. Previous employers
  I. Reason for leaving last job
  J. Type of job for which one is applying
  K. References
  L. Resume (optional)
  M. General physical health
  N. Race

V. Expectations of employer and employee

  A. Employer expectations

    1. Cooperation
    2. Honesty
    3. Initiative
    4. Willingness to learn
    5. Willingness to follow directions
    6. Dependability
    7. Enthusiasm
    8. Acceptance of criticism
    9. Loyalty and respect

INFORMATION SHEET

10. Full day's work for full day's pay

11. Notification of termination or of absence

B. Employee expectations

1. Salary

2. Safe working conditions

3. Training

4. Introduction to co-workers

5. Explanation of policies, rules, and regulations

6. Duty responsibilities and changes

7. Evaluation of work

8. Discipline for breaking rules

9. Honest relationship

10. Notification if employment is terminated

11. Respect

VI. Personal attributes or attitudes desired by employers during personal interviews

A. Enthusiasm and interest

(NOTE: This includes taking pride in your work and being willing to do more than your share when needed.)

B. Dedication and dependability

(NOTE: This involves being at work on time and regularly. It also means you should readily follow directions.)

C. Alertness, quickness of mind

(NOTE: You should always look for unsafe situations that could injure workers or damage property, and you should constantly look for more efficient working practices.)

D. Honesty and integrity

(NOTE: Employees should give truthful information both to customers and to their employer.)

E. Desire to work

INFORMATION SHEET

F. Desire to help others

G. Desire to improve one's self

(NOTE: Better employees always look for ways to increase their knowledge. This benefits both the employer and the employee.)

VII. Proper conduct during the interview

A. Greet interviewer with a warm smile

B. Call interviewer by conventional title and last name (Mr., Mrs., Miss, or Ms. Jones)

C. Introduce yourself

D. Shake interviewer's hand firmly, if offered, while looking at interviewer in the eye

E. Sit only after interviewer has asked you to be seated

F. Sit and stand erect

G. Do not place objects on the interviewer's desk

H. Let the interviewer take the lead in the conversation

I. Answer questions completely

J. Be polite and courteous

K. Have resume and examples of work available for quick reference

L. Make an extra effort to express yourself clearly and distinctly

(NOTE: Think through every answer, use proper grammar, do not swear, avoid use of slang, and look interviewer in the eye.)

M. Be sincere and enthusiastic

N. Avoid distracting or irritating habits

(NOTE: Things to avoid include smoking, chewing gum, eating candy, finger tapping, giggling or squirming, and any distracting nervous activity.)

O. Do not try to flatter the interviewer

P. Tell the truth about qualifications and experiences

Q. Speak well or not at all of former employers and associates

INFORMATION SHEET

R. Be positive

S. Accept competition gracefully

T. Watch for signs that the interview is over

(NOTE: Interviewers frequently conclude by clearing the desk, folding the application file, or indicating with facial expression or body language that the information desired from the applicant is complete.)

U. Thank the interviewer

V. Leave promptly at completion of interview

W. Make contacts alone

(NOTE: Taking two or three friends along does not help you get the job.)

APPLYING FOR A JOB
UNIT I

ASSIGNMENT SHEET #1--PREPARE A RESUME

Directions: Prepare a resume using the standards and example provided below.

A. Standards for a resume:

1. Logically organized
2. Neatly typed
3. Error free
4. In outline form
5. Limited to one page if possible
6. Honest listing of qualifications and experiences

B. Example of a resume:

Name: John A. Doe
Address: 123 Anywhere Street, Hometown, State, 12345
Telephone: (555) 505-1212

Age: 18 years
Height: 5' - 9"
Weight: 165 pounds
Health: Excellent
Marital Status: Single

Education: Expect to graduate from high school, May, 1982

Subjects studied: Algebra - 2 semesters
Geometry - 1 semester
Basic Electronics - 1 semester
Industrial Electronics - 1 semester

Student activities: FFA
Vice-president, VICA
Secretary, Baptist youth fellowship

Work experience: Chute hand, Nelson Livestock Auction Co., summers of 76, 77, and 78

Electrician's Helper, Anseo Electric, summer 1979

Tune-up Man, Larry's Auto Electric, summer 1980

Lab assistant, Industrial Electronics class, fall, 1979 and spring, 1980

ASSIGNMENT SHEET #1

References:

Mr. L.E. Vator
Hometown High School
Hometown, State, 12345

Mr. Lenz Volta, Owner
ABC Electrical Co.
Capitol City, State 12378

Date: ____________________ Signature: ____________________

APPLYING FOR A JOB
UNIT I

ASSIGNMENT SHEET #2--WRITE A LETTER OF APPLICATION

Directions: Using the letter standards, information to be included, and example, write a letter of application.

A. Compose the letter to meet the standards below:

   (NOTE: Your instructor will be glad to help you. A typing or business and office class would probably be willing to type for you.)

   1. Attractive form
   2. Logical arrangement of information
   3. Free from smudges or typographical errors
   4. Free from spelling or grammatical errors
   5. Brief and to the point; leave the details for the resume
   6. Positive in tone
   7. Clearly expressed ideas

B. Include only appropriate information in a letter of application

   1. Type of position for which one is applying
   2. Reason interested in position and firm
   3. Ways one's training meets the employer's needs
   4. Explanation of personal qualifications
   5. Mention of resume

ASSIGNMENT SHEET #2

Example:

Mr. John Jones
Personnel Director
Jones Television Company
Box 123
Anywhere, USA 12349

Dear Mr. Jones:

Please consider me for the job of television repairman that you advertised in the Anywhere Journal.

The skills I have learned in my high school vocational electronics and television courses should qualify me for this job. I have had experience in all of the elementary skills required to perform television repair and maintenance, including safety.

I will be graduating from high school in May, and I would like to become an electronic repairman. A more complete description of my qualifications is given in the enclosed resume.

I would appreciate the opportunity to interview any time at your convenience. I can be reached by telephone at 505-1212 after 3:30 p.m. or by mail at 123 Anywhere Street, Hometown, State 12345.

Sincerely yours,

John A. Doe

Encl. 1

APPLYING FOR A JOB
UNIT I

ASSIGNMENT SHEET #3--COMPLETE AN APPLICATION FORM FOR A JOB IN ELECTRONICS

(NOTE: Falsification could lead to not being hired or to dismissal.)

A. Fill in every blank, and put "does not apply" in those blanks where information not relevant is requested.

APPLICATION FOR EMPLOYMENT

Date ______________________ Position applied for ______________

Name ______________________ Height ______ Weight ______ Age ______

Address ______________________ Telephone No. ______________
(Street or RFD) (City) (State)

Social Security No. ______________________

Birthdate ______________________ Birthplace ______________
(Month) (Day) (Year) (City) (State)

CHECK ALL THAT APPLY:

_____ Female
_____ Male
_____ Single
_____ Married
_____ Widowed
_____ Divorced
_____ Separated

_____ Own home
_____ Rent
_____ Board
_____ Live with parents
_____ Live with relatives
_____ Purchasing home

____
Number and age of dependents
____
Relationship of dependents.
____
Business or occupations of father:
____
or Husband ______________

Interested in: Temporary work ____ Full-time ____ Part-time ____ Saturday only _____

Salary expected ______________________

Are you responsible for your entire support? _____ Others who are dependent on you for their support: Number _____ Ages ______________

Nature of any physical defects ______________________

Recent illnesses ______________________

Date of last physical examination ______________________

EDUCATION	Circle grade completed	Name of School	Location	Major Subject	Year Graduated
Elementary	1 2 3 4 5 6 7 8				
High	1 2 3 4				
Business or Vocational	1 2 3 4				
College or University	1 2 3 4 5 6				
Night or Correspondence	1 2 3 4				

ASSIGNMENT SHEET #3

Give details of any other educational training ______________________________

____

What are your hobbies?

In case of illness or emergency, notify:

Name ______________________

Address ______________________

Relationship ______________________

Telephone ______________________

Why do you feel qualified for the position for which you are applying?

____

____

PREVIOUS EMPLOYMENT
(Last employment first)

(NOTE: Previous employers may be contacted.)

From	To	Name & address address of employer	Department, position duties, and salary	Reason for leaving
Month Year	Month Year			
Month Year	Month Year			
Month Year	Month Year			
Month Year	Month Year			

ASSIGNMENT SHEET #3

PERSONAL REFERENCES

(Do not give names of relatives or former employers)

Name	Address	Occupation
1.		
2.		
3.		

B. The final part of your application will be completed by a professional interviewer or your instructor. You will be asked additional questions about your educational background, family experiences, hobbies, and other items that reflect your interest and life-style. Refer to item VII of the Information Sheet for this part of the assignment sheet.

Do Not Write In Space Below

Interviewed by:

Personality ____________________

Attitude ____________________

Ambition and Initiative ____________________

Other remarks

Calmness ____________________

Physical qualities ____________________

Intelligence ____________________

Leadership ____________________

Appearance and grooming ____________________

Work best suited for ____________________

APPLYING FOR A JOB
UNIT I

ASSIGNMENT SHEET #4--WRITE A FOLLOW-UP LETTER AFTER AN INTERVIEW

Directions: Using the standards, points to be included, and the example below, write a follow-up letter after a job interview.

A. Follow these standards:

1. Error free
2. Clean, neat, and arranged attractively
3. Free from spelling, punctuation, and grammatical errors
4. Sent within a day or two after the interview

B. Include these points in a follow-up letter:

1. An expression of appreciation for the interviewer's time and interest
2. A summary of personal qualifications and interest in the position

(NOTE: Make this last bid for the job a prime example of your excellent work habits. Make the letter as clean, neat, and well worded as possible.)

Example:

Mr. John Jones
Personnel Director
Jones TV Company
Box 19
Anywhere, U.S.A. 77704

Dear Mr. Jones:

Thank you for interviewing me for the electronics job in your firm. I feel that working for Jones TV Company would be enjoyable and that I could do the repair work that the job requires. I hope that I will have the opportunity to prove my worth.

The application form you gave me is enclosed.

I will be available for work May 15. You may call me at my home after 3:30 p.m. The number is 377-3303.

Sincerely yours,

John A. Doe

Encl.

APPLYING FOR A JOB
UNIT I

NAME ______________________________

TEST

1. Match the terms on the right to the correct definitions.

_____a. A brief summary of one's qualifications and experiences that is used in applying for a job

_____b. The extras provided by an employer such as paid vacations, sick leave, and insurance protection

_____c. Recognition received for outstanding achievement

_____d. The experience, education, and physical characteristics which suit a person to a job

_____e. The courses taken and the skills acquired in school or through work experience

_____f. The clubs, organizations, and social or church groups in which one participates

1. Award
2. Extra-curricular activities
3. Fringe benefits
4. Qualifications
5. Resume
6. Vocational preparation

2. List four sources for locating job openings.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

3. List three methods of applying for a job.

a. ______________________________

b. ______________________________

c. ______________________________

4. Select information that may be asked for on an application form by placing an "X" in the appropriate blanks.

______a. Grandfather's age

______b. Name and address

______c. Phone number

______d. Shoe size

______e. Age, height, weight

______f. Education

______g. Number of brothers and sisters

______h. Experience

______i. Next of kin

______j. Horsepower of your car's engine

______k. Previous employers

______l. Reason for leaving last job

______m. Favorite sports

______n. Type of job for which one is applying

______o. References

5. Distinguish between employer and employee expectations by placing an "X" next to the employer's expectations.

______a. Cooperation

______b. Honesty

______c. Initiative

______d. Salary

______e. Safe working conditions

______f. Training

______g. Willingness to learn

______h. Willingness to follow directions

______i. Introduction to co-workers

_____j. Dependability

_____k. Enthusiasm

_____l. Acceptance of criticism

_____m. Loyalty and respect

_____n. Full day's work for full day's pay

_____o. Notification of termination or absence

6. Select attributes or attitudes desired by employers during a personal interview by placing an "X" in the appropriate blanks.

_____a. Alertness, quickness of mind

_____b. Long wavy hair

_____c. Dedication and dependability

_____d. Enthusiasm and interest

_____e. New car

_____f. Honesty and integrity

_____g. Desire to work

_____h. Beard

_____i. Flashy clothes

_____j. Desire to help others

_____k. Desire to improve one's self

7. Select examples of proper conduct during a job interview by placing an "X" in the appropriate blanks.

_____a. Arrive five minutes late; gives the impression that you are busy

_____b. Sit and stand erect

_____c. Call interviewer by his or her first name

_____d. Answer questions completely

_____e. Put a hat or coat on the interviewer's desk

_____f. Greet interviewer with a warm smile

_____g. Sit down immediately upon entering the room _____h. Shake interviewer's hand firmly if offered, while looking at interviewer in the eye

_____i. Be polite and courteous

_____j. Use all of the cute slang expressions

_____k. Be sincere and enthusiastic

_____l. Thank the interviewer

_____m. Chain smoke

_____n. Speak well or not at all of former employers and associates

_____o. Flatter the interviewer

_____p. Leave promptly at completion of interview

8. Prepare a resume.
9. Write a letter of application.
10. Complete an application form for a job in electronics.
11. Write a follow-up letter after an interview.

(NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

APPLYING FOR A JOB
UNIT I

ANSWERS TO TEST

1. a. 5
    b. 3
    c. 1
    d. 4
    e. 6
    f. 2

2. Any four of the following:

    a. Classified ads
    b. Employment offices
    c. Local labor union business offices
    d. School officials
    e. Workers in electronic occupations

3. a. Letter
    b. Telephone
    c. In person

4. b, c, e, f, h, i, k, l, n, o

5. a, b, c, g, h, j, k, l, m, n, o

6. a, c, d, f, g, j, k

7. b, d, f, h, i, k, l, n, p

8. Evaluated to the satisfaction of the instructor

9. Evaluated to the satisfaction of the instructor

10. Evaluated to the satisfaction of the instructor

11. Evaluated to the satisfaction of the instructor